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METALS & ALLOYS

Devoted to the Advancement of Scientific Metallurgy

●

Current Metallurgical Research at the Bureau of Standards

H. S. RAWDON

X-Ray Metallography in 1929

Part IV

GEORGE L. CLARK

The Effect of the so-called Utah Shale "Fluxes" on the Dispersion of Lead in Copper-Lead Alloys

G. L. CRAIG

National Metal Congress

●

NUMBER 4
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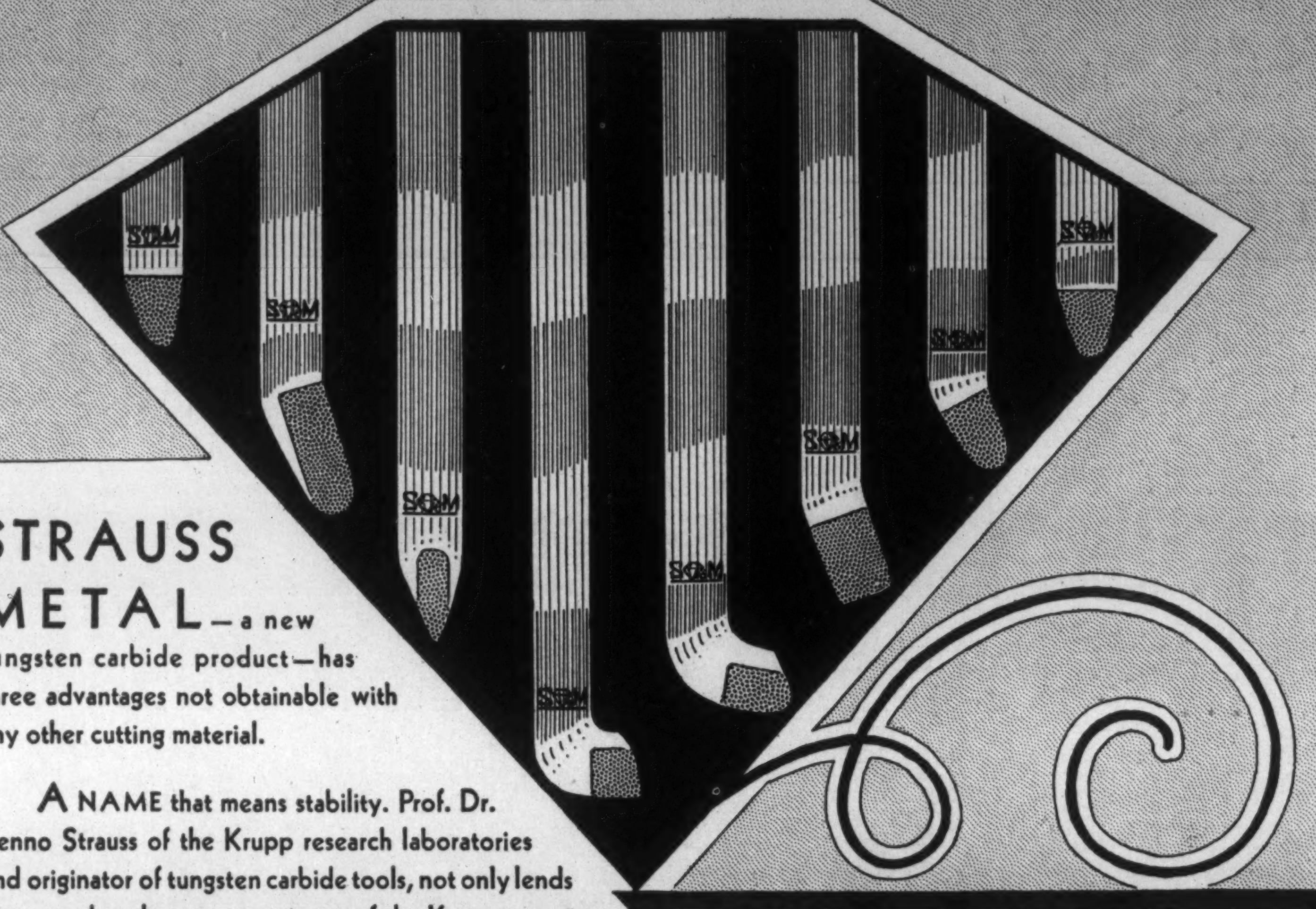

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PUBLISHER'S PAGE

Note—On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

Let's Have Your Views

Three issues of METALS & ALLOYS having appeared, the publishers decided it would be a good idea to find out what was actually being thought and said about the paper by various classes of people constituting the metallurgical public. Accordingly, we took advantage of a number of recent conventions largely attended by metallurgists and others interested in the manufacture, application and testing of alloys and made a particular point of asking representative people for their frank opinion. One significant fact immediately became apparent. We did not encounter a single person among those interviewed who did not know about METALS & ALLOYS. Furthermore, with the exception of a very small minority, all of these people felt that there was a real need for the paper and that our undertaking was worthy of encouragement. The small minority (considerably less than 10% of those interviewed, we should say) were people who felt they are already deluged with technical reading matter and that another paper merely added to their burdens. In many instances these people changed their views when we explained to them that METALS & ALLOYS did not duplicate the work of any existing publication.

While all the encouraging and complimentary things said to us in these interviews were welcome and decidedly cheering, we valued even more some of the intelligent criticisms that various people took the trouble to present to us in detail. The most frequent criticism was a suggestion that we steer clear of making the paper too "technical" and that we devote at least a part of our space to articles interesting to so-called "practical" men throughout the metallurgical industries, such as foundrymen, electroplaters, etc. Also, it was frequently suggested that we should arrange for a certain number of articles which would explain important metallurgical developments in a way that would be appreciated by business men in the metal industries.

We intend to profit by these suggestions and have already taken steps to secure such material because we feel that METALS & ALLOYS should have something to say to all types of people having any interest in metallurgy and the use of metallurgical products. As a matter of fact, that ideal was quite clearly set forth in our original prospectus.

However, in pursuing that policy we must not allow ourselves to be frightened away from publishing important contributions to the advancement of metallurgical science just because they are highly technical in appearance. We find it a little hard to understand how a publication devoted to the advancement of scientific metallurgy ever can be other than highly technical if it is to be of any real use.

In mapping out these editorial policies we are determined not to allow ourselves to be influenced by the attitude of prospective advertisers. We have had enough experience in selling advertising in other technical publications to realize that the average advertising manager instinctively shies at a paper which appears to him as being extremely technical or, as he more usually puts it, "highbrow." But we feel confident that these men can be made to see that a paper which it will be profitable to advertise in must necessarily be a paper which editorially meets the requirements of its readers.

The group of men who have already subscribed for METALS & ALLOYS probably have more influence on the specification and purchase of metallurgical products than any other people in America. If we are able so to edit our paper that these people will find it really helpful, then it will automatically offer the advertiser a splendid opportunity to talk directly to them about the products which he is offering for sale.

What we want right now from our readers more than anything else is suggestions as to subjects to be covered in our articles and reviews. If the readers will submit their suggestions we probably shall be able to interest competent men to deal with the subjects suggested, owing to the wide acquaintanceship of our editorial director, Dr. H. W. Gillett, and his associate, Mr. Richard Rimbach.

We also want letters from our readers expressing opinions and criticisms of the articles that we are publishing. Far from resenting criticism, writers on technical subjects invariably welcome the expression of divergent views and in that way many valuable facts will be brought out and METALS & ALLOYS will become truly a clearing house for information on all matters relating to the advancement of scientific metallurgy and the manufacturing industries dependent thereon.

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. GILLETT, *Editorial Director.*

"Metals Week"

The short phrase "Metals Week" certainly represents a lot. During the week of September 9th, at Cleveland, there met the American Society for Steel Treating, both the Institute of Metals Division and the Iron and Steel Division of the Mining Engineers, the Iron and Steel Division of the Mechanical Engineers, and the American Welding Society. Several committees of the American Society for Testing Materials held meetings. In all the sessions, there were some 90 technical papers presented, which will be abstracted in due course.

The National Metal Exposition showed the products of some 240 exhibitors, and there were visits scheduled to some 25 industrial plants of Cleveland and vicinity.

Besides all this, almost everyone in the metallurgical fields dealt with by these societies was there, and many acquaintanceships were renewed and new ones made. These unscheduled conferences in the lobbies do not appear on the official program, but they are by no means the least valuable part of such a convention. The bigger the convention, and the larger the attendance, the more chance there is of seeing the men with whom one wants to discuss his problems. From this point of view, at least, the big convention is all to the good.

The handling of papers and discussions is, however, more difficult the larger the meeting. That end was handled surprisingly well. While everything had to run on a strict time schedule to give time for discussion, and there was little chance for the "knock down and drag out" type of oral discussion, which we all enjoy hearing to liven things up, yet there was no undue rush about the sessions.

Microphones and chairmen like Professor Waterhouse, who kept the speaker and the microphone linked up by moving one or the other, solved the difficulty of hearing the speaker for even the largest audiences. That of visibility of the screen was not so well solved, many of the slides of large tables being a total loss. With preprints available, it would appear that running a long series of tables or even of micrographs on the screen is scarcely necessary in a crowded program. Curves can be grasped by the audience, but slight differences in a series of micrographs are not well followed.

McQuaid's lucid presentation of his paper on "Practical Fundamentals of the Nitriding Process" without either preprint or slides makes one wonder if more slideless talks would not be an improvement.

The high spots of the non-ferrous sessions of the Institute of Metals will be separately reported. In the various iron and steel sessions it was noticeable that there was equal, real interest in the papers presented by Eaton, Sauveur, French, Epstein, Herty, Kinzel, Krivobok, Harder, Sykes, Dornin and others, on fundamental facts and theories, and in those by Davey, Boston, Sperry, Fink, Luerssen, etc., on methods of testing and research, as on the more "practical" papers by Knowlton, McQuaid, Merten and most of the papers on nitriding.

It was plain that metallurgists are really using the newer testing tools and are perfectly willing to use more as soon as they are developed so as to be reliable. While tensile testing and metallographic examination are still the mainstays in the evaluation of the properties of metals, macro etching, fatigue testing, impact testing, special hardness testing methods, X-ray spectrography and radiography are relied upon more and more for supporting evidence, while tests for machinability, wear resistance, hardenability, dilatation and presence of internal flaws are all being sought that will give more precision than heretofore.

The paper by Sperry brought out discussion evidencing that while the statement that the new fissure detector car was "sweeping the tracks clear of the transverse fissure menace" was premature, everyone is hopeful that with the refinements that will come in time the statement can be made an accurate one. Tests for such elusive qualities as "body" in steel, and stethoscope testing for quality of welds illustrate how the metallurgist is to-day chasing down the elusive properties of his metals, and using every tool that one can reasonably hope to apply.

He is also willing to think about what the results mean, and to suggest lines of attack that involve still more years of groping for the perfection of new tools and of studying out the interpretation of the new results. Eaton's paper on "Dilatation of Steel during Quenching" contains ideas for a lifetime's work.

Another variable that the metallurgists seem determined to control sooner or later is the iron oxide content of a steel bath before final deoxidation. Lacking a rapid method of determining the actual iron oxide content, and quite evidently having decided that the less iron oxide there at that time the better, Dornin suggests controlling it by making new slags, and Herty hints at control by thickening the slag. Truly clean steel is not yet in sight, but cleaner steel is bound to come, and come soon.

The search for improved quality is on in all quarters, and by all means. The revolutionary suggestion was made that railroads might well pay more for carefully made and tested billets for forging.

The refrain of all the papers and discussions was that "much further work is needed, is contemplated, and will disclose valuable new facts." Coming "Metals Weeks" will certainly record the results of more research, more detailed research, and research by better methods.

As one comes away with 5 pounds of preprints of technical papers from the sessions, and 50 pounds of catalogs and pamphlets from the exposition, he wishes he were twins so that he could have gotten still more help and inspiration from the meetings, the show and the personal contacts. Next year, one will wish to be triplets.

Current Metallurgical Research at the Bureau of Standards[1]

By H. S. Rawdon[2]

Since the Bureau of Standards is a public institution, it is believed that reports on the activities of any particular division of the Bureau to those most directly concerned with the work of that division are worth while and will be appreciated. It is especially fitting that the work along metallurgical lines be reported through a journal which deals with metallurgy as a whole, since most of the work cannot be classed definitely as relating only to ferrous or to non-ferrous metallurgical subjects.

The Advisory Committee. In planning and conducting the metallurgical research at the Bureau, close contact with the "practical" phases of industrial metallurgy as well as the more specialized problems of the various research laboratories is maintained.

Heretofore there have been two Metallurgical Advisory Committees dealing with ferrous and non-ferrous problems, respectively. Meetings were held on successive days, though most of the members attended both days and showed equal interest in the two fields. At the 1929 meeting the two committees agreed to coalesce, thus recognizing the fact that the basic principles of metallurgy should be the main concern in metallurgical research.

That the metallurgical work of the Bureau is being directed along lines of some interest to the public is indicated by the attendance at the Advisory Committee meetings. At the 1929 meeting there were in attendance about 135 individuals, only 40 of whom attended but one of the two sessions. The attendance each day was about 115. Over 80 came from out of town, Chicago, Moline, Urbana, Detroit, Boston, Hartford, Toronto and Montreal being some of the distant cities represented. Other government departments were represented by about 20 individuals. Half a dozen "alumni" of the metallurgical division, now in industrial employment, were present. The attendance of so large and representative a group of metallurgists shows a public interest in the work of the Bureau that is decidedly heartening to the staff. Another evidence of this interest is the fact that several firms sent metallurgists to the Bureau during the past year to act as leaders in the series of colloquia held by the metallurgical division for the continued education of its members.

Information Work. The "information work" of the division requires considerable time. In a recent 12-month period, metallurgical questions were discussed with over 1100 visitors, about 100 coming from 15 foreign countries. Replies to over 4000 letters requesting information on metallurgical subjects were prepared. In order to facilitate the replying to the wide variety of inquiries received, the current metallurgical literature dealing with the Bureau's field is continuously indexed. In order to reduce the labor of preparing individual replies to frequently recurring inquiries, circulars, letter circulars and general articles are often prepared, the printed or mimeographed material serving as the reply.

Some of these circulars are quite extensive, as, for example, that on light alloys, which, with its bibliography, covers 400 printed pages. Permission to translate this into German has recently been requested. A similar circular on zinc and cadmium is in preparation. The Bureau also plans to cooperate with Engineering Foundation in its "Alloys of Iron Research," which aims to summarize the work which has been done in the extensive field of iron alloys as the Bureau has in its circulars on copper, nickel, invar and light alloys.

Another similar task was the preparation of an outline of the principles of heat treatment.[3] There have been many calls for this publication and it is now being used as a text-book in some universities and also the Naval Post-graduate School of the Naval Academy.

Papers of a general nature prepared are illustrated by those on steel requirements of the aircraft industry[4] and on corrosion problems as applied to power plants[5] which were written for technical society meetings on request.

Service of the types mentioned, as well as membership on committees of technical societies, may properly be expected of the members of the staff of a government laboratory. This is frequently done at the expense of time that otherwise could be devoted to research. A certain amount of routine testing and minor research for other government departments and other divisions of the Bureau also is done.

Research Projects Completed in the Metallurgical Division. During the past fiscal year, several projects, or subdivisions of projects, that had been under way for years were completed to the "publication stage," consequently it has been possible to plan work along some new lines or to undertake new phases of continuing projects.

Among the projects recently completed are: flow in low carbon steel at elevated temperatures,[6] blistering during the enameling of cast iron,[7] surface cooling of steels when quenched in various media,[8] accelerated laboratory corrosion test methods for zinc-coated steel,[9] wear resistance and mechanical properties of railroad bearing bronzes at different temperatures,[10] steel for case-hardening—normal and abnormal steel,[11] strain markings in mild steel under tension,[12] study of the hydrogen-antimony-tin method for the determination of oxygen in cast iron,[13] laboratory corrosion tests of mild steel with special reference to ship plate,[14] rubber binders for foundry cores,[15] use and behavior of protective coatings on underground pipes,[16] corrosion embrittlement of duralumin—results of weather exposure tests,[17] effect of corrosion, accompanied by stress, on the tensile properties of sheet duralumin,[18] bearing bronzes with and without zinc,[19] effect of service on endurance properties of rail steel.[20]

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[1] **Published with the approval of the Director of the Bureau of Standards.**

[2] **Chief, Division of Metallurgy.**

[3] *Trans. Amer. Soc. Steel Treat.*, **14**, 502, 744, 893 (1928).

[4] Yearbook, Amer. Iron & Steel Inst., **1928**, p. 350; *Iron Age*, **122**, 1161 (1928); *Iron Trade Review*, **83**, 1105 (1928); *Blast Furnace & Steel Plant*, **16**, 1436, 1579 (1928).

[5] *Trans. Amer. Soc. Mech. Engrs., Fuels & Steam Power*, 51-6, Jan.-Apr., 1929, p. 19; *Iron Age*, **123**, 666 (1929).

[6] *Canadian Machinery*, **39**, 31 (1928).

[7] *Trans. Am. Ceramic Soc.*, **11**, 595 (1928) (fuller account soon to be published in *Bureau of Standards Journal of Research*).

[8] *Trans. Amer. Soc. Steel Treat.*, **15**, 217 (1929); *Fuels & Furnaces*, **6**, 1515 (1928).

[9] *Bureau of Standards Journal of Research*, **1**, 255 (1928); *Res. Paper* **10**; *Min. & Met.*, **9**, 501 (1928).

[10] *Bureau of Standards Journal of Research*, **1**, 343 (1928); *Res. Paper* **13**; *Proc. Amer. Soc. Test. Matls.*, **28**, Pt. 2, 298 (1928); *Canadian Railway Jour.*, Feb., **1929**, p. 1.

[11] *Bureau of Standards Journal of Research*, **1**, 423 (1928); *Res. Paper* **14**; *Industrial Gas*, **7**, 20 (1929).

[12] *Bureau of Standards Journal of Research*, **1**, 467 (1928); *Res. Paper* **15**; *Eng. News-Record*, **1928**, p. 244.

[13] *Bureau of Standards Journal of Research*, **1**, 701 (1928); *Res. Paper* **25**.

[14] *Bureau of Standards Journal of Research*, **2**, 431 (1929); *Res. Paper* **42**.

[15] *Bureau of Standards Letter Circular* **252**; *Metal Ind.*, **26**, 470, 511 (1928); *Foundry*, **56**, 892 (1928); *India Rubber Jour.*, **76**, 3 (1928); *Foundry Trade Jour.*, **39**, 392 (1928).

[16] *Bull. Am. Petroleum Inst.*, **10**, No. 2, 78 (1929).

[17] Nat'l Advis. Com. for Aeronautics, *Tech. Note* **304**, 1929; *Am. Inst. Min. & Met. Eng., Tech. Pub.* **173**, 1929; *Metal Stampings*, **2**, 219 (1929); *Am. Machinist*, **70**, 601 (1929).

Publications, in press, deal with: effect of oxidizing conditions in accelerated electrolytic corrosion tests,[21] hot aqueous solutions for the quenching of steel,[22] observations on the iron-nitrogen system,[23] turning of metals with shallow cuts at high speeds,[24] comparison of the properties of hand-puddled and Aston-process wrought iron,[25] and an automatic metallographic polishing machine.[26]

Pending Metallurgical Publications. The following subjects have been practically completed by the metallurgical division and the reports are being prepared for publication: creep of metals at elevated temperatures, effect of excessive cold rolling on the hardness of copper, properties of very pure nickel and thorium, improvements in the vacuum fusion method for determination of oxygen in iron and steel, failures in fusible plugs for steam boilers protection, note on magnesia refractories for laboratory steel furnaces, sand abrasion methods for testing wear-resistance of metals and wear-resistance of chromium plates and nitrided steels.

Other Bureau Work Relating to Metals. Published Bureau work relating to metals, which recently has been done outside the metallurgical division, comprises: note on the effect of repeated stresses on the magnetic properties of steel,[27] thermal expansion on magnesium and its alloys,[28] physical properties of dental materials (gold alloys and accessory materials),[29] reflecting power of beryllium, chromium and several other metals,[30] apparatus for thermo-magnetic analysis,[31] thermal expansion of tantalum,[32] new determination of the melting point of palladium,[33] and tests on steel reinforcing bars.[34]

In addition, there are a considerable number of projects of metallurgical interest under way, such as: soil corrosion, magnetic testing, electrical conductivity, stability of resistance standards, alloys for electrical resistors, storage battery alloys, dental alloys, thermal expansivity of chromium and other metals and alloys, airplane engine type testing, aircraft tubing, airship girders, endurance testing of aluminum and magnesium alloys and of aluminum-coated duralumin, pyrometry, radiography, thermoelectric properties of pure metals and alloys against platinum, purification of platinum-group metals, platinum laboratory ware, corrosion of engine radiators and pumps by anti-freeze solutions, corrosion of household oven-linings, fire-resistance, lubrication, methods of chemical analysis and sampling, standard samples for chemical analysis, quantitative spectrographic examination of proof gold and of platinum-iridium alloys, as well as the study of the spectral lines of other metallic elements, and varnishes, electroplating (particularly chromium, iron and the effect of addition agents in copper deposition), copper roofing, welding, comparison of Brinell-Rockwell and Brinell-Vickers hardness readings, bridge structures, wire rope, thread locks, elastic hysteresis in metals, effect of temperature on elastic moduli, wear of instrument pivots, wear of dies used in extruding bricks, refractories and corrosion problems in paper making, textile work and dry cleaning.

Many of these projects have the cooperation of Research Associates from industry, and in many the metallurgical division cooperates.

Among the most interesting of these projects are the development of a high speed endurance testing machine in which the test specimen is floated on air streams and made to vibrate by other impinging air streams (Figure 1); testing of a series of bridge towers made of steel of 35,000, 45,000 and 55,000 lbs./sq. in. yield point, respectively, the tests requiring the use of a 10,000,000-lb. testing machine; and the work on the wear of dies for extrusion of bricks, in which preliminary tests have indicated that, by the choice of the proper alloy, the wear can be reduced to a tenth of that which is now experienced.

Special Equipment. Other divisions are cooperating with the metallurgical division in the design and construc-

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[18] Nat'l Advis. Com. for Aeronautics, *Tech. Note* **305**, 1929; Preprint No. 42, Amer. Soc. Test. Matls., 1929 meeting.

[19] Preprint No. 49, Amer. Soc. Test. Matls., 1929 meeting, and will appear soon in *Bureau of Standards Journal of Research.*

[20] *Bureau of Standards Tech. News Bull.* **144**, 32 (1929), and *Bureau of Standards Journal of Research,* **2**, August, 1929.

[21] To appear soon in *Bureau of Standards Journal of Research.*

[22] To appear soon in *Bureau of Standards Journal of Research;* also to be presented at September meeting, Amer. Soc. Steel Treating.

[23] To appear soon in *Bureau of Standards Journal of Research;* also to be presented at September meeting, Amer. Soc. Steel Treating.

[24] To appear soon in *Bureau of Standards Journal of Research.*

[25,26] To appear soon in *Bureau of Standards Journal of Research* and in METALS & ALLOYS.

[27] *Bureau of Standards Journal of Research,* **1**, 721 (1928); *Res. Paper* **26**.

[28] *Bureau of Standards Journal of Research,* **1**, 771 (1928); *Res. Paper* **29**.

[29] *Bureau of Standards Journal of Research,* **1**, 867 (1928); *Res. Paper* **32**.

[30] *Bureau of Standards Journal of Research,* **2**, 343 (1929); *Res. Paper* **39**.

[31] *Bureau of Standards Journal of Research,* **2**, 659 (1929); *Res. Paper* **50**.

[32] *Bureau of Standards Journal of Research,* **2**, 887 (1929); *Res. Paper* **62**.

[33] *Bureau of Standards Journal of Research,* **2**, 931 (1929); *Res. Paper* **65**.

[34] Preprint, Amer. Soc. Test. Matls., 1929 meeting.

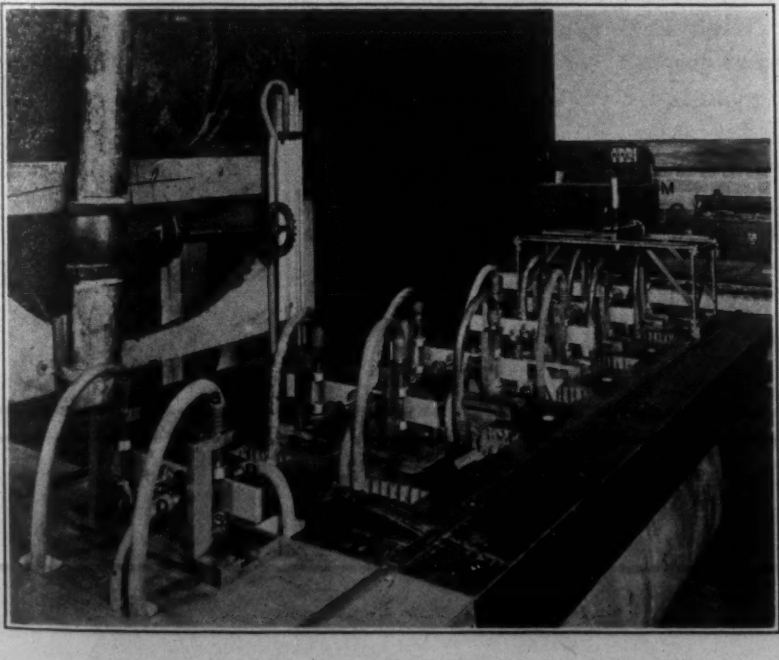


Figure 1—High-Speed Endurance Testing Apparatus. The Bar is Supported on Air Streams, S, and Set in Vibration by Impinging Air Streams, D. It Vibrates at 210 Cycles (Approximately) per Second, the Amplitude Being Controlled by the Device, A; M is the Microscope Used to Measure the Amplitude. The Rate of Vibration is Determined by Means of a Stroboscope

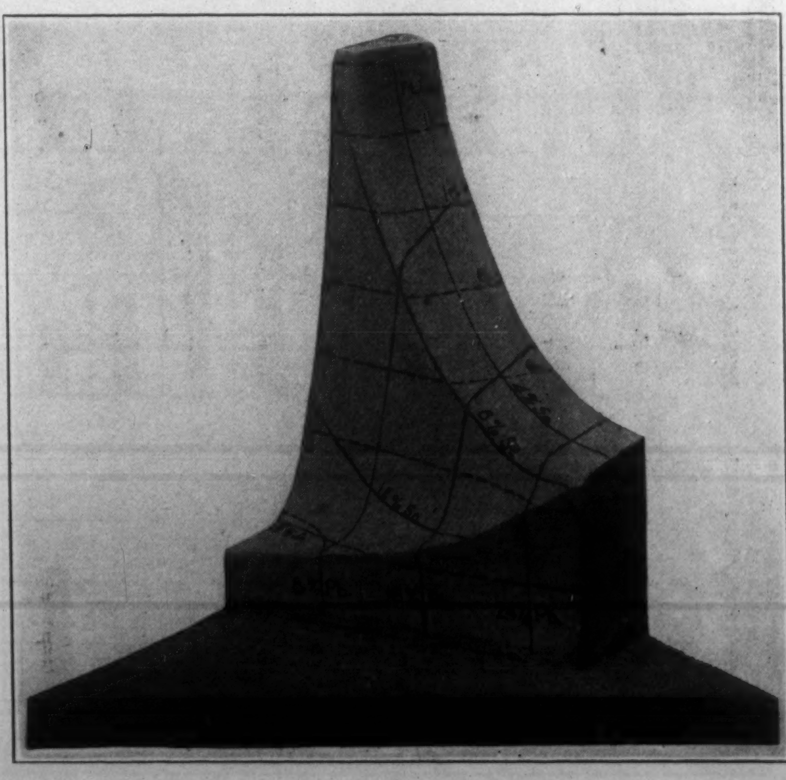


Figure 2—Three-Dimensional Diagram Showing the Variations in Impact Strength of Cu-Sn-Pb Alloys

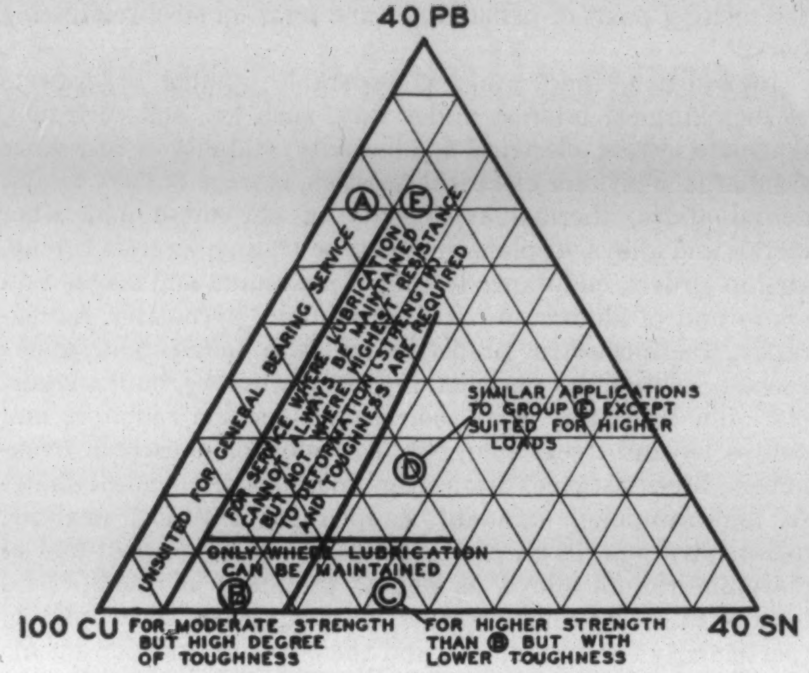

40 PB
A
E
UNSUITED FOR GENERAL BEARING SERVICE
FOR SERVICE WHERE LUBRICATION CANNOT ALWAYS BE MAINTAINED BUT NOT WHERE HIGHEST RESISTANCE TO DEFORMATION (STRENGTH) AND TOUGHNESS ARE REQUIRED
SIMILAR APPLICATIONS TO GROUP E EXCEPT SUITED FOR HIGHER LOADS
D
ONLY WHERE LUBRICATION CAN BE MAINTAINED
B
C
100 CU
FOR MODERATE STRENGTH BUT HIGH DEGREE OF TOUGHNESS
FOR HIGHER STRENGTH THAN B BUT WITH LOWER TOUGHNESS
40 SN

Figure 3—Suitability of Cu-Sn-Pb Alloys for Bearing Service

tion of apparatus for study of the thermal conductivity of metals and of a beta-ray spectrograph. The latter appears to offer possibilities for the study of the nature of the A_2 transformation in iron, i. e., what "beta" iron really is. The metallurgical division is also constructing apparatus for the taking of X-ray spectrograms of specimens at elevated temperatures.

Research Associate Projects in the Metallurgical Division. *Bearing Bronzes.*—In continuation of the previous work on bearing bronzes, the Bunting Brass and Bronze Company, through its Research Associate, is cooperating with the Bureau in a comprehensive study of the effect of various additions or impurities, such as zinc, phosphorus, antimony and nickel upon the copper-tin-lead bronzes. Figure 2 shows one of the solid models which are used to show the properties of the ternary system, without additions. The property shown by the height of the model above the triangular base being, in this case, impact resistance at room temperature. Figure 3 shows a general summary as to the types of bearing service for which the ternary leaded bronzes are fitted on the basis of the various tests made. Figures 4 and 5 show how little the properties are affected by the presence of 4 percent zinc in the alloys, while Figure 6 gives a key to the compositions of Figures 4 and 5. Work on the effect of additions of other elements is in progress.

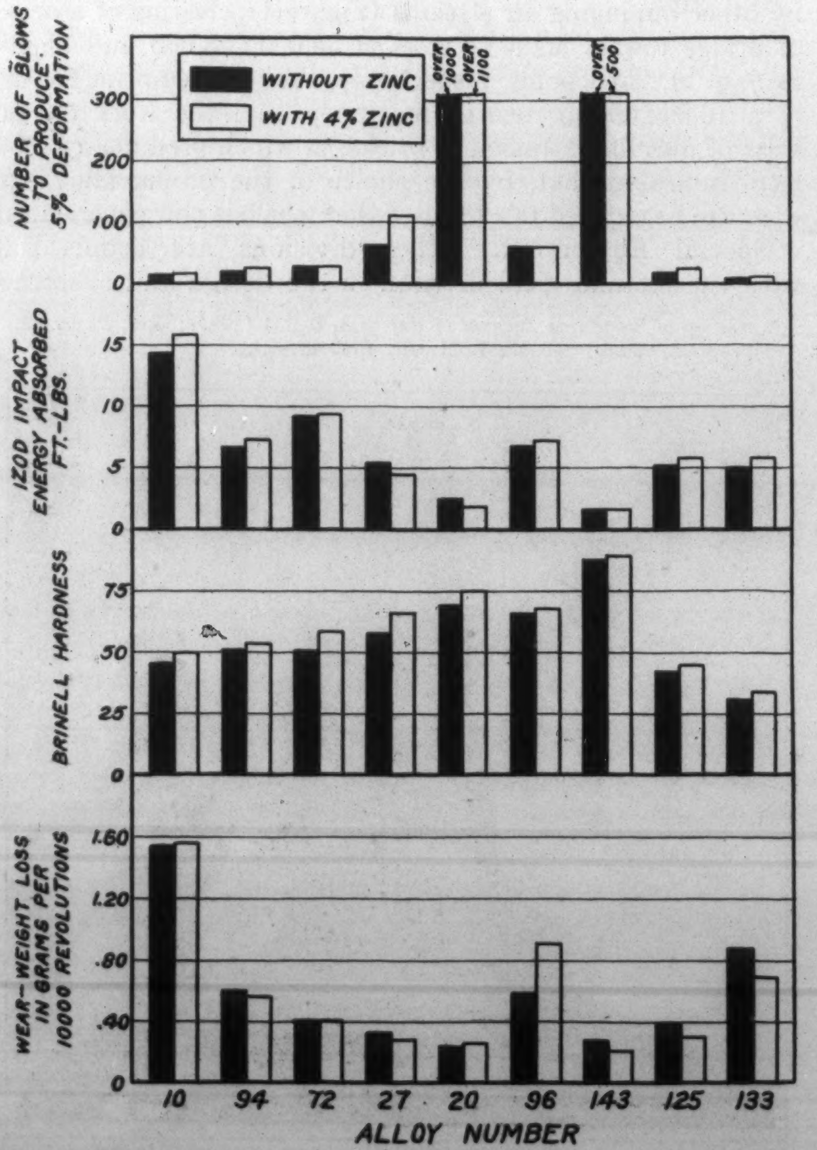


Figure 4—Comparative Properties of Cu-Sn-Pb Alloys with and without Zinc at Room Temperature

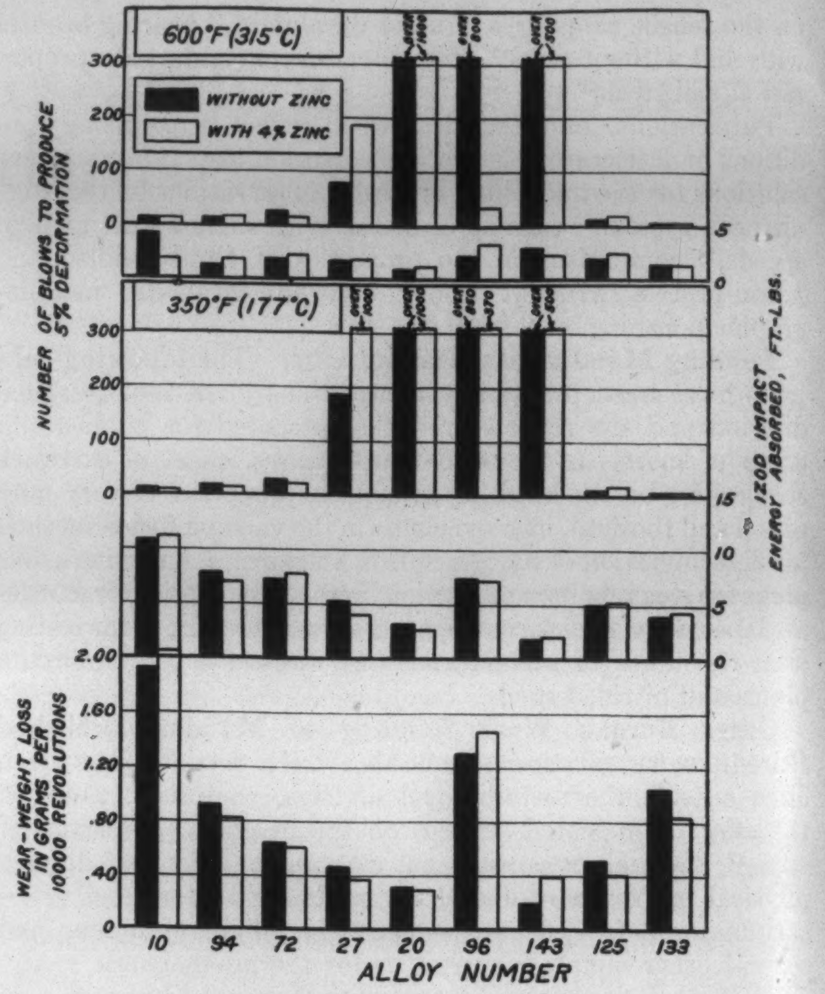


Figure 5—Comparative Properties of Cu-Sn-Pb Alloys with and without Zinc at Elevated Temperatures

High Temperature Properties. The Midvale Steel Company has a Research Associate at the Bureau engaged in a cooperative study of high temperature properties of commercial

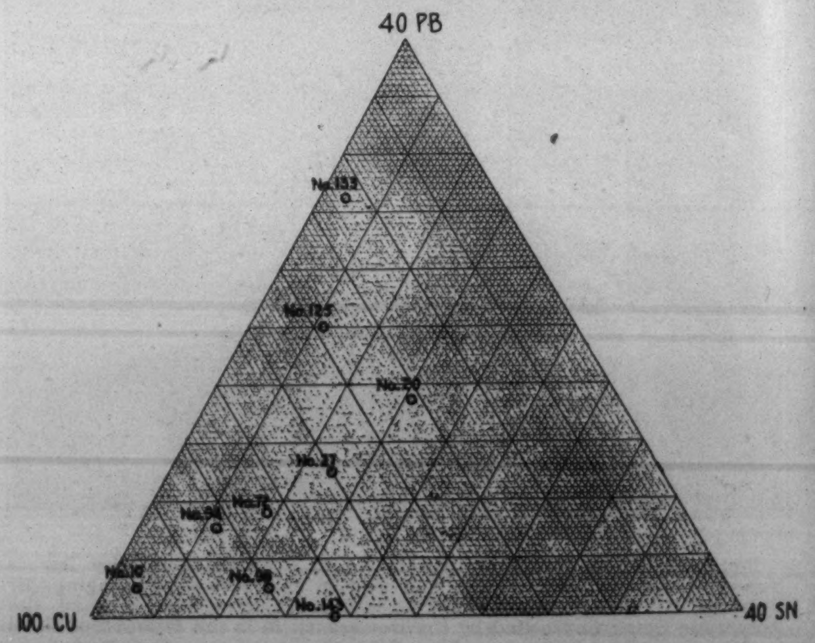

40 PB
No.133
No.125
No.20
No.27
No.72
No.94
No.10
No.96
No.143
100 CU
40 SN

Figure 6—Key to Compositions of Alloys of Figures 4 and 5

alloy steels, while the Bureau itself is working on the iron-nickel-chromium series, which is the basis for a great many of the useful heat-resisting alloys. Figure 7 shows the general tendencies for cast alloys of this series on the basis of the stresses producing 1 percent elongation in the first 1000 hours at 1000° F. (540° C.). Further work is in progress at other temperatures and on the effect of additions of tungsten, molybdenum or silicon. Other work in contemplation deals with the question of carbide precipitation under load at high temperatures in the 18 percent Cr, 8 percent Ni type of steels with carbon above and below 0.07 percent.

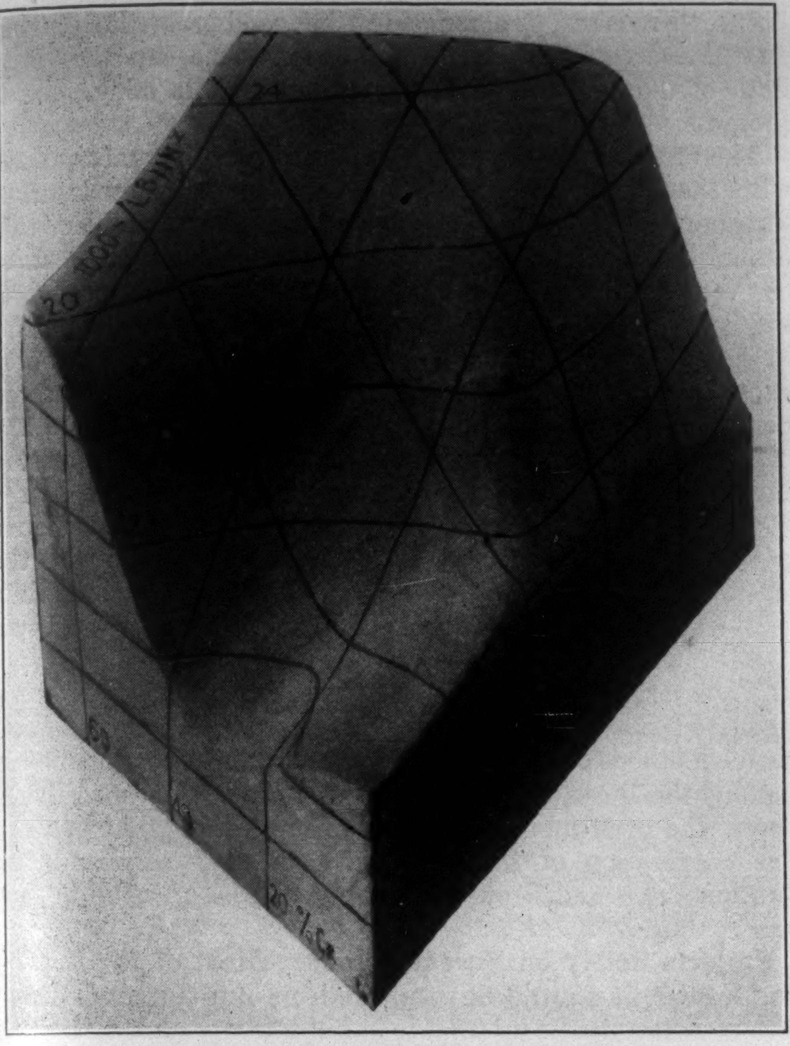


Figure 7—Three Dimensional Diagrams Showing the Stresses Producing 1% Deformation in the First 1000 Hours at 1000° F. (540° C.) in the Fe-Ni-Cr Alloys

Steel Castings. The Steel Castings Development Bureau has a Research Associate studying the problems of the steel casting industry. The Bureau of Mines is also cooperating in this work. Figure 8 illustrates one of the problems under study. Casting A, made in a dry sand mold, which has been chipped off at the junction (light band in the photograph) of the keel-block test bar and the head, shows sound metal, whereas casting B from the same ladle but made in a green sand mold, is porous. Various means are being studied

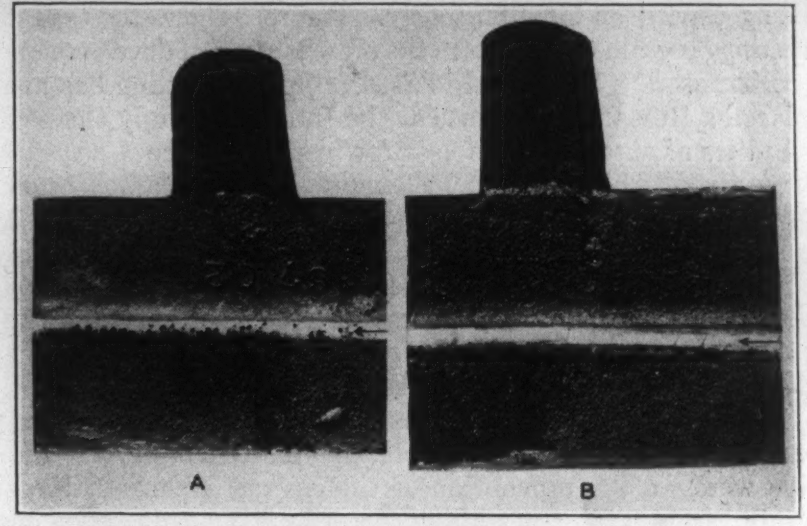
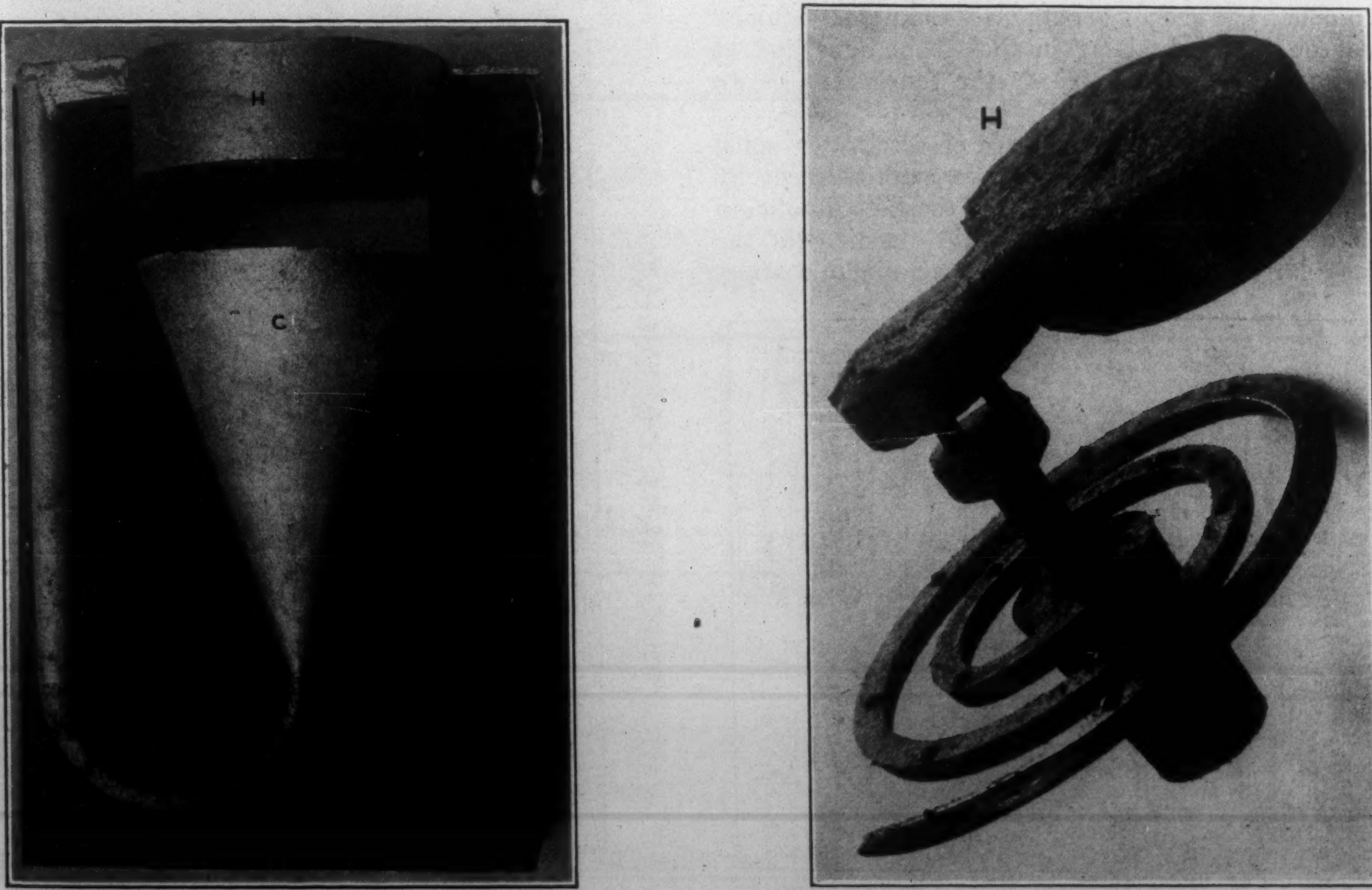


Figure 8—Steel Cast in Green and in Dry Sand as "Keel-Block" Test Bars. A, Green Sand (Note the Porous Condition of the Steel, Indicated by the Arrow); B, Dry Sand; Sound Metal



(a) (b)

Figure 9—Testing Castings Which Are Being Used in the Study of Solidification Shrinkage and Fluidity of Metals and Alloys
(a) Casting Used in the Study of Shrinkage during Solidification of Metals and Alloys. The Conical Portion, C, is the Part Used, H is the Pouring Head
(b) Casting Used in the Study of the Fluidity of Metals. The Length of the Spiral is Taken as a Measure of Fluidity of the Molten Metal at the Casting Temperature. H is the Pouring Head

for eliminating this porosity without the use of deoxidizers which would result in low ductility. A little work has been done on the use of boron as a deoxidizer, which, though not yet fruitful, still appears to offer possibilities. Beryllium has also been tried and acts much like aluminum.

The installation in the near future of a large "ironless" induction electric furnace and a 960-cycle motor generator set will make possible the study of alloy steels for castings. This equipment will permit the making of heats of steel of 400 lbs. or even larger.

Shrinkage and Fluidity. The American Foundrymen's Association, which has previously supported work on the pyrometry of cast iron, in the Heat and Power Division, now has a Research Associate in the Metallurgical Division, studying methods for the determination of shrinkage that occurs in metals and alloys during solidification. The Bureau itself is studying the methods for determining the ability of metals and alloys to fill the mold during casting, the two projects being carried on simultaneously. Figure 9 shows the type of castings used in these tests in the present stage of development.

Bismuth. The Cerro de Pasco Copper Company has just placed a Research Associate at the Bureau to study the possibilities of extending the uses for bismuth, since it appears that metallic bismuth can be produced at costs much below present prices, if quantity production can be assured. A general survey of possible metallurgical applications for bismuth, with due regard for the economic phases, has been planned. One of the first phases for study will relate to the use of lead-bismuth alloys for storage batteries; in this the electrical and metallurgical divisions will cooperate.

Projects Supported by Transfer Funds from Other Government Departments. *Duralumin and Magnesium.*—Active work on the prevention of the embrittlement of duralumin through intercrystalline corrosion has been carried on for over four years, funds allotted by the Navy, Army, National Advisory Committee for Aeronautics and by the Bureau itself being used. Valuable and active cooperation has been given by producers. The long-continued exposure tests, under the severe conditions obtaining in the Canal Zone and at Hampton Roads, continue to verify the conclusions drawn from previous laboratory studies.

Cold water quenching and avoidance of accelerated aging make duralumin much more resistant to embrittlement by corrosion, although it appears that even the best duralumin sheet, unprotected, will become embrittled in time in the presence of chlorides, as in "salt air." An aluminum coating, such as that on "Alclad"-sheet, is by far the best protective coating so far found. In cases such as airplane tubing, since "Alclad" tubing is not yet available for some lighter-than-air structures where the slight decrease in strength cannot be borne, there is real need for some other good protective coating. In the search for such a coating, long-time exposure tests, both of duralumin and of magnesium and its alloys, are in progress.

The most recent phase of the work in the laboratory deals with the increase in corrosion rate when the alloy is under static or repeated stress, a phase of the general problem that cannot be carried out by exposure tests. While static loading has very little effect in this respect, repeated stress accelerates the corrosive attack very markedly. The outstanding point of the recent work is the fine performance of aluminum coated duralumin under simultaneous severe corrosion and repeated stress somewhat above the normal working stresses (Figure 10).

Lead-base Babbitts.—A new project which is to be supported during the next fiscal year, by transfer funds from the Army, deals with conservation of tin, and is being studied at the request of the Assistant Secretary of War. This deals with the possibility of replacement, for some uses, of tin-base babbitt bearings by lead-base bearings, either of the common type, that is, antimony-hardened, or the "alkali-hardened" type. The American Society for Testing Materials has requested work on white bearing metals for several years. The background on testing methods obtained in the work on bronze bearing metals has put the Bureau in a position where it now feels ready to attack the even more difficult problem of the white metals. The cooperation of the National Lead Company and the Bunting Brass and Bronze Company will be of value in this work.

Projects Solely on Bureau Funds. Most of the important continuing projects supported on Bureau funds have been reported almost up-to-date in publications already issued.

Blistering of Cast Iron on Enameling.—One important project which has been under way for five years and has just been

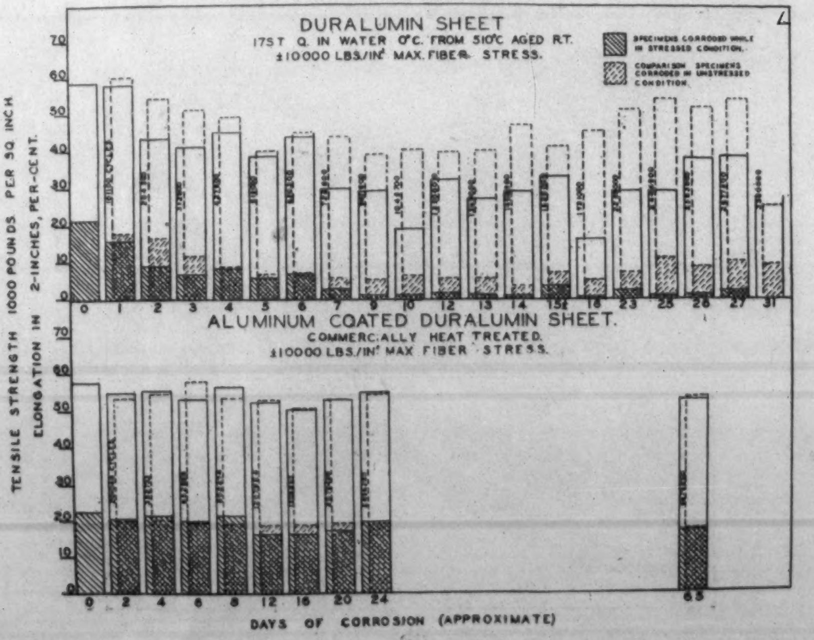


Figure 10—Comparative Tensile Properties of Bare and Aluminum-Coated Duralumin Sheet after Corrosion for the Periods Shown by Intermittent Immersion in $NaCl + H_2O_2$ Solution, with Simultaneous Repeated Flexure at 10,000 Lbs./Sq. In. at 75 Cycles per Minute (Approximately)

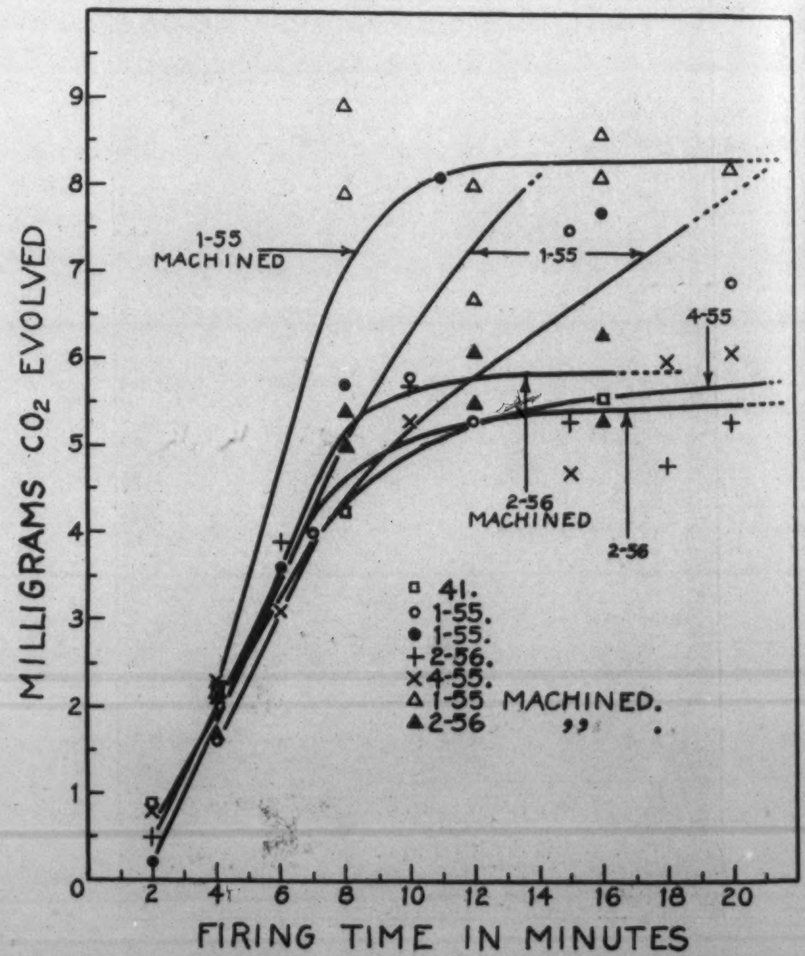


Figure 11—Rates of Gas Evolution from the Surface of Blistering and Non-Blistering Cast Irons

Sample 1-55 in Ordinary Condition was a Strongly Blistering Iron; after Being Machined It Did Not Blister completed, deals with the phenomena of blistering of cast iron on enameling, and was jointly studied by the metallurgical and ceramic divisions. The cause of the blistering, occurring during the enameling of castings from some irons, appears to lie in the presence of an extremely thin, chilled surface layer, so thin that it seems not to have been recognized before. The breakdown of cementite in this layer produces very finely divided and very reactive graphite or temper carbon which is readily oxidized by air and evolves CO and CO_2 at a stage in the enameling process at which the enamel will retain the gas bubbles. This gas-forming reaction probably occurs with all irons, the rate of formation being the important thing. If the rate slows up during the critical periods of enameling, blistering may be avoided; otherwise blistering will be met. Figure 11 shows how the rates of gas evolution from non-blistering irons fall off during a certain period of the firing of the enamel while that from the blistering iron (1-55) keeps up. The same figure shows also that when the surface layer of a "blistering" iron is removed, the material below the surface gives a diminishing rate of gas evolution during the critical firing period. If the surface layer be removed by machining, deep sand blasting or pickling, the tendency toward blistering is much reduced, as is shown in Figure 12.

Deep-drawing Steel.—This problem was suggested to the Bureau by steel makers and users, and from preliminary work it appears that spinning the sheet into a cone over mandrels of varying tapers in an ordinary lathe, no special equipment being necessary, offers enough promise to justify further study. Sheets will fail over mandrels of different tapers according to their "deep-drawing qualities." Figure 13 shows the set-up for this test in its present state of development.

Iron–nitrogen System.—Another project on which work has been under way for years and has recently been pushed to completion, is a study of the iron–nitrogen system.

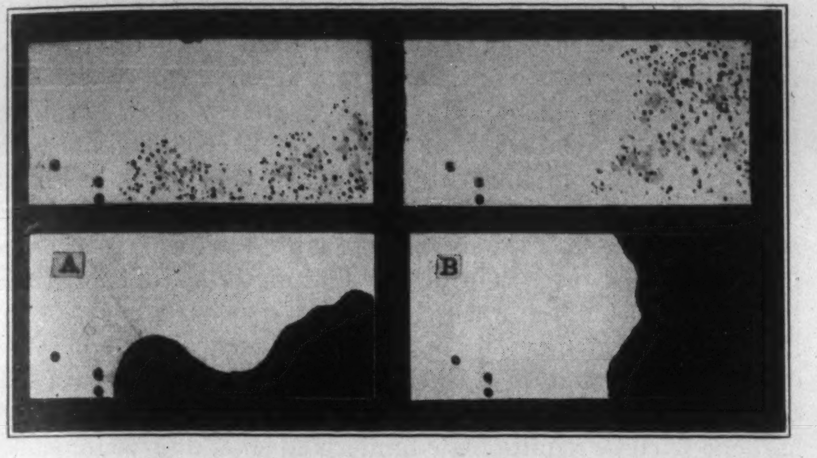


Figure 12—Effect of Removing a Thin Surface Layer from a Blistering Iron. The Original Surface Blisters, the Machined Surface Does Not Note How the Blistered Areas in the Unlettered Rectangles Correspond with the Unmachined Areas (Black) of the Lettered Rectangles. The Plates were Machined at a Slight Angle. The Three Larger Black Circles Constitute an Identification Mark. After the Iron Places were Covered with the Ground Coat They were Fired for 10 Minutes at 875° C. (1605° F.); the Cover Coat was Then Applied and the Plates Fired 8 Minutes at 800° C. (1470° F.)

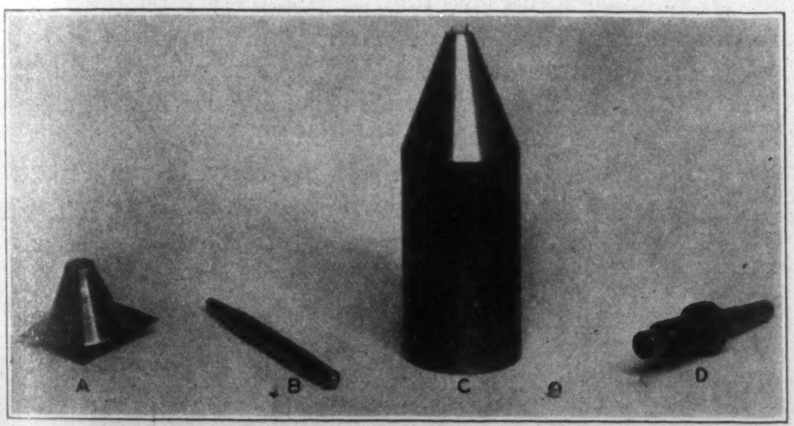


Figure 13a

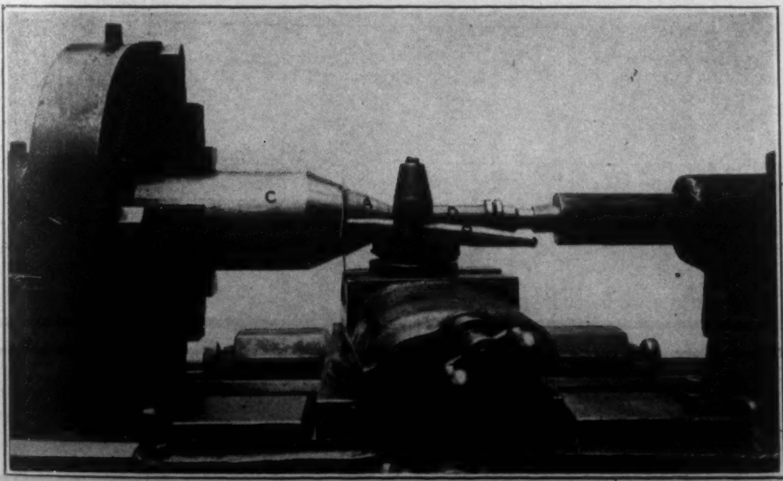


Figure 13b

Figure 13—Apparatus for Test-Spinning of Sheet Steel over a Conical Mandrel

(a) A, a Sheet after Spinning; B, the Spinning Tool with a Ball-Bearing and C, One of the Tapered Mandrels over Which the Sheet is Spun; D, Tail Piece Which Bears against the End of the Mandrel.

(b) Lathe Showing the Assembly for the Test. The Parts are Lettered to Correspond with *a*

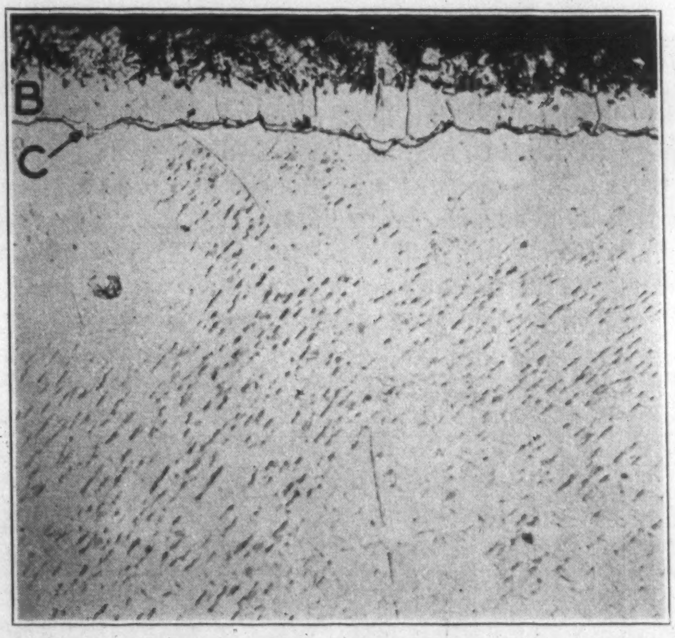


Figure 14—Layers on the Surface of Nitrided Iron. The Outer Layer, A, is Obtained by Nitriding at Low Temperatures (170 hrs., 425° C. Used in This Case) and Decomposes at Higher Temperatures

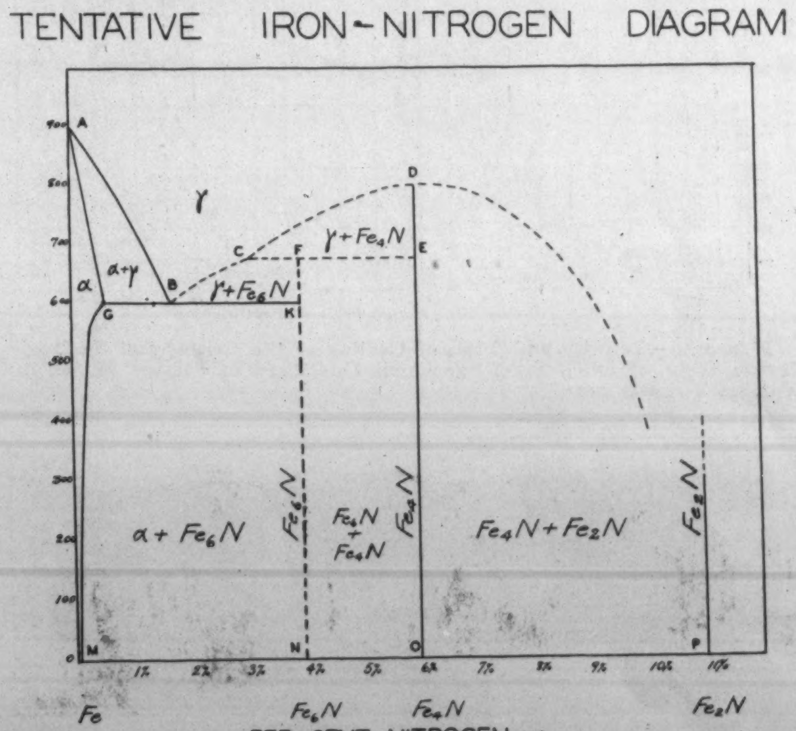


Figure 15—Tentative Iron-Nitrogen Diagram

An understanding of this system is necessary as the base line for the study of the commercial nitriding steels. The work resulted in the recognition of a hitherto undescribed layer on the surface of iron nitrided at low temperatures. The fact that this layer is unstable at high temperatures will account for its previous lack of recognition. It is shown in Figure 14. The existence of this layer, and other metallographic X-ray and thermal analysis evidence, led to the suggestion of a modified iron-nitrogen diagram (Figure 15) which, on account of the difficulties of working with a system in which some phases are unstable, must be considered as tentative only.

Hot Aqueous Quenching Media.—There is need for quenching media in the hardening of steel which will have cooling rates intermediate between those of cold water, brine or other rapid aqueous coolants, and those of oils. Hot water, brine and caustic soda appear to offer possibilities as is shown by the curves of Figure 16, from a forthcoming paper. In the present state of knowledge, however, they must be used with caution. Further work in this field, relating to the concentration and the circulation of the coolants, is in progress.

Finish Turning of Metals.—An important production problem in metallurgy relates to machining, to the ability of tools to cut and of metals to be cut. Rough turning of steel has been previously studied at the Bureau[35] from both points of view.

In more recent work, laws quite similar to those that seem to hold for rough turning have been found to apply in finish turning. In order to evaluate the performance of tools in this work the simple expedient was adopted of mounting two tools in the tool-holder as shown in Figure 17. As the leading tool wears, the trailer tool will begin to cut. The point at which the trailer starts to cut coincides enough with a poor finish on the steel to serve as a satisfactory break-down point, though this is not so clearly marked as is tool failure in rough turning tests.

The effect of cobalt, nickel, molybdenum, arsenic, antimony, phosphorus, sulphur, copper, tin, aluminum, titanium and tantalum in tungsten-chromium-vanadium high speed tools has been studied in the rough and finish turning. More work is in progress on the machinability of various alloy steels, and preliminary work has been begun on methods of evaluating the performance of the new tungsten carbide tool materials.

Rubber Binders for Foundry Cores.—Rubber cement used as a core binder behaves in a remarkable manner; it stands up against the scouring action of hot metal, yet breaks down as the metal sets, so that the core disintegrates and the sand may be poured out from the interior of the casting.[36] Cores made with some of the special, chemically treated rubber or "thermoprene" cements can be made as strong as linseed oil cores. Dr. Moldenke[37] has characterized the discovery of the rubber binders as a "distinct achievement." In cooperation with various rubber companies and foundries, more work has been done in this field. The high permeability of rubber-bonded cores makes possible the use of finer core sand, thus securing a better finish on cored surfaces. The materials offer distinct possibilities as mold washes and core pastes, while a very interesting possibility lies in the application, as by spraying, of a high concentration of the binder to the surface alone of the core, the interior being only slightly bonded. Such "case hardened" cores require little binder and should serve for some uses. In order to study the possibility of avoiding the use of flammable solvents, rubber latex has been tried. While not all types of latex are satisfactory, some are as satisfactory as the thermoprene cements.

Properties of Pure Metals.—Nickel and thorium of unusually high purity were made available, in small quantity, by commercial producers and rhodium of extremely high purity was prepared by the chemical division. The properties of these metals are being studied by many divisions of the Bureau. Work of the metallurgical division has given a new figure for the X-ray lattice constant of rhodium (3.77Å). The properties of the platinum-rhodium alloys are being studied. Some of the data obtained are shown in Figure 18. The working

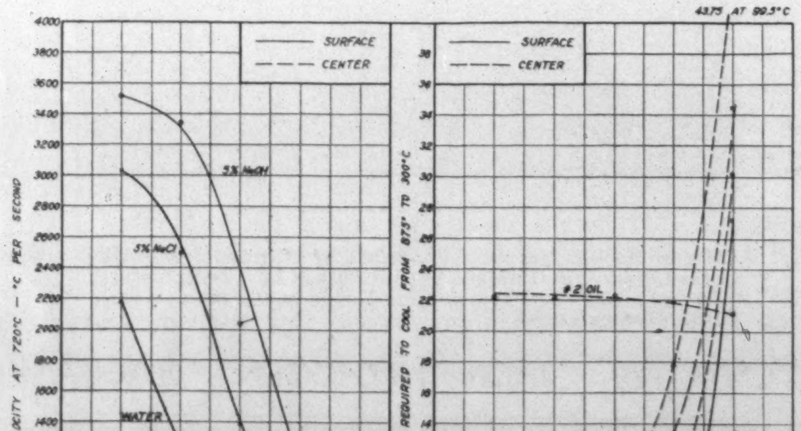


Figure 16—Velocity and Time of Cooling at the Center and Surface, Respectively, of Small Steel Specimens Quenched in Various Media at Various Temperatures

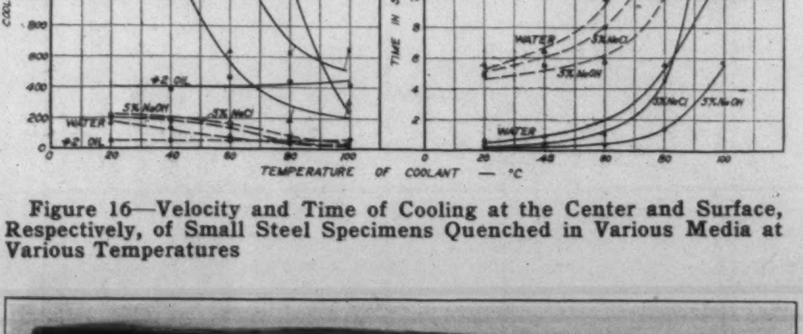


Figure 17—Tool-Holder with Leader and Trailer Tool for Study of the Finish-Turning of Metals

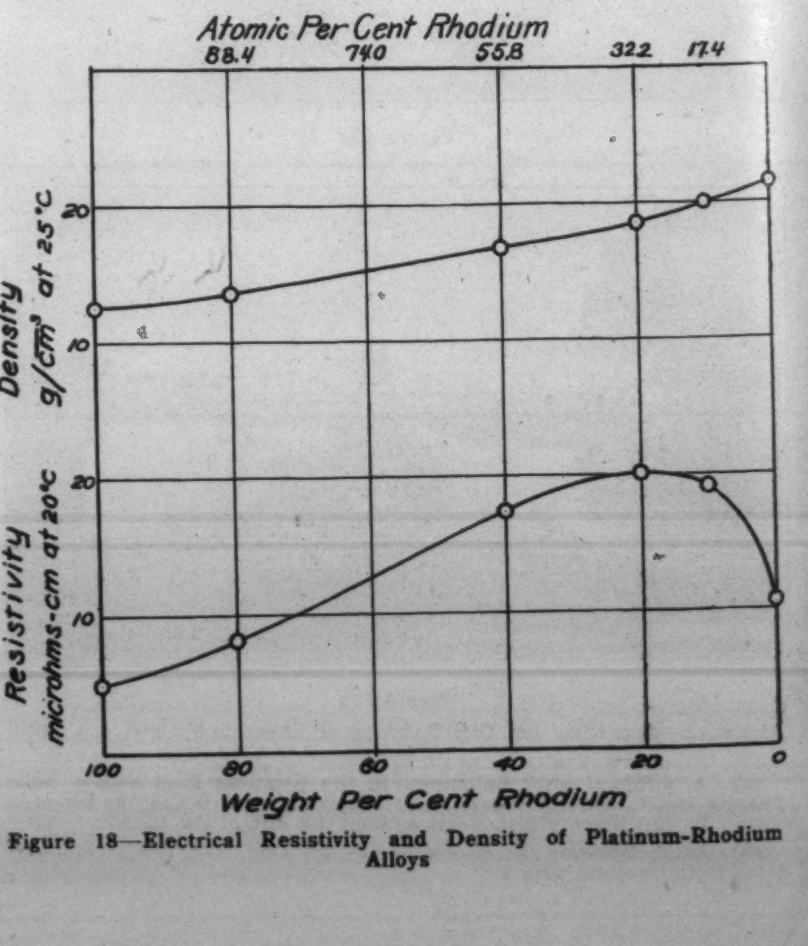


Figure 18—Electrical Resistivity and Density of Platinum-Rhodium Alloys

of pure rhodium into wire for use as electric furnace resistors has given some difficulty, but has been accomplished by hot swaging. Wire of 80 percent rhodium, 20 percent platinum has given very good service for resistors in tests at the Bureau.

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[35] *Proc. Amer. Soc. Mech. Engrs.*, **48**, 533 (1926); *Mech. Eng.*, **49**, 339 (1927).

[36] *Letter Circular* **252**. This will be mailed on application to the Bureau of Standards, Washington, D. C.

[37] *Iron Age*, **123**, 45 (1929).

According to present plans, attention will be concentrated, in the immediate future, on the preparation and study of pure iron. The determination of oxygen and nitrogen in iron by vacuum fusion methods has emphasized the fact that the so-called "pure" electrolytic iron, ordinarily used in research work, is generally quite seriously contaminated. Some attention has been paid to the solubility of carbon in ferrite and to the thermal critical points of iron, and reported in discussion of papers by other workers who have brought up the question of the effects of oxygen and nitrogen.

Gases in Metals.—It has been hoped to begin supplementing the analytical side of this problem by the actual study of the solubility of gases in metals (and this is still planned for early attention). However, details of analytical technique have continued to occupy the center of the stage, and further improvements have been made. With the present-day interest in the study of inclusions in steel in which the Bureau has shared, it becomes increasingly evident that there is a real need for an accurate method for the determination of total oxygen. *Analyses* by residues *do* not always recover the total oxygen, higher oxygen content being shown by vacuum fusion methods with some types of inclusions. Vacuum fusion methods appear to give higher nitrogen than chemical methods in some materials, and there is some evidence that the difference in nitrogen content by the two methods may bear a relation to certain properties of the steel. With such interpretation of results in view, extreme precision is required. The improved train for determination of oxygen and nitrogen by vacuum fusion is shown in Figure 19. Guest workers from The American Rolling Mill Company and Watertown Arsenal, who have recently installed vacuum-fusion apparatus, were given the courtesies of the Bureau laboratories.

Resistance of Metals to Severe Service Conditions.—Metallurgists are continually faced with problems of the failure of metals under severe service. As a basis for the development of alloys that will last longer, suitable methods for laboratory testing of their resistance to a given set of conditions must first be sought. The study of metals at high temperatures has already been touched on in this report.

Corrosion test methods have received much attention at the Bureau and the study of the effect of varying degrees of aeration in submerged corrosion testing is now under way.

The study of wear testing methods, in respect to metal-to-metal wear, to wear in the presence of a lubricant as in bearings, and to wear by non-metallic abrasives, is one of the major projects. Half a dozen types of wear testing apparatus are in use.

The endurance of metals under repeated stress is being studied jointly by the engineering mechanics section and the metallurgical division. Batteries of rotary beam machines of low speed, high speed flexural machines, and 2 Haigh (axial tension and compression) endurance machines (one of these having been loaned by Watertown Arsenal) are being kept busy. The relationship between rotary beam and axial loading endurance tests is receiving attention.

Rail Failures.—Endurance testing has been used in the study of rail steel before and after service; the results have been fully reported. The study of the endurance properties of steel from rails that have failed by transverse fissures, of alloy rail steel, zirconium-treated steel and of heat-treated rail steel is being continued. The work has focused attention on the internal "shatter cracks" as nuclei for transverse fissures and raised the question of the cause of the cracks. Since there is some evidence that they occur during the cooling of the rail (presumably in the hot bed), the high-temperature properties of rail steel are being studied.

Steels from rails that meet the usual specification requirements and are indistinguishable by room temperature tests have been found to vary in their high-temperature properties. Most rail steels show a sag in the temperature-ductility curves and in a certain temperature range their tensile strength is low and their ductility, also (Figure 20). The degree of "secondary low ductility" and the exact temperature range at which it occurs vary in different steels and appear to have some relation to the previous thermal history, i. e., the rate of cooling after rolling. The cause of this phenomenon is still very obscure; likewise its bearing on the transverse fis-

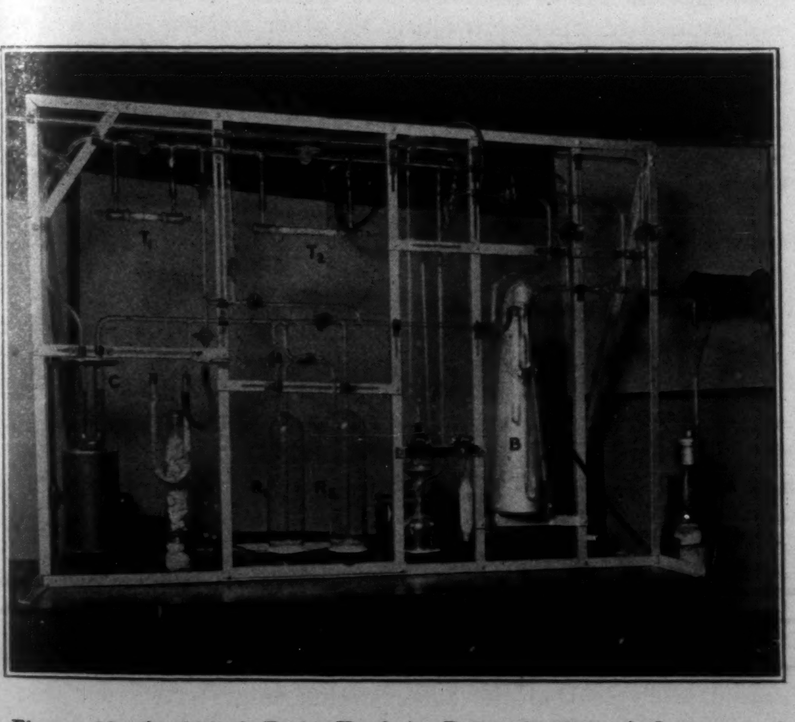

Figure 19—Analytical Train Used in Determination of Oxygen and Nitrogen in Steel by the Vacuum Fusion Method
A, High-Frequency Furnace with Its Loading Device;
B, 2-Stage Mercury Diffusion Pump;
C, Tube Containing Copper Oxide Heated, by Means of the Furnace Shown below It, to 300° C.; T_1 and T_2, Absorption Tubes for Water Vapor and Carbon Dioxide, Respectively; R_1 and R_2, Reservoirs to Control the Pressure of the Gases in the Analytical System also to Furnish a Known Volume in Which Residue Gas, Chiefly Nitrogen, May Be Determined Volumetrically

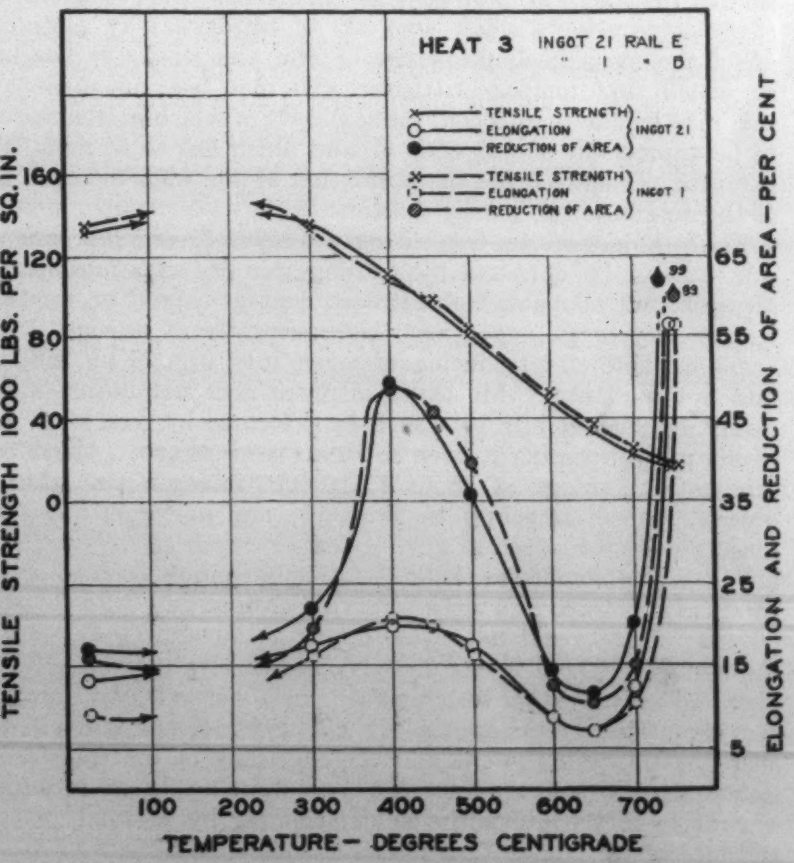

Figure 20—High-Temperature Tensile Properties of a Rail Steel. Two Ingots from the Same Heat were Used

sure problem. The economic importance of rail failures, however, makes it worth while to follow up any lead that seems to offer any promise of a better understanding.

Bridge Wire and Notch Propagation.—A new important project has arisen through the desire of the engineers, contractors and fabricators of the wire for the Mt. Hope bridge, near Providence, that the Bureau study the causes for the failure of the wire in the bridge cables. The wire was heat treated and hot galvanized. The use of heat treated wire for the Mt. Hope bridge and the Ambassador bridge at Detroit was an innovation in bridge construction. The failure of many wires in the the Mt. Hope bridge during erection, while the cables were under low stresses, made necessary the taking down of the cables with a resulting high financial loss. The wire passed exacting tests and appeared to be a decided metallurgical advance over the materials previously used. Its failure is most puzzling and disconcerting. Until the variables responsible for the failure are determined, civil engineers are barred from the use of highly desirable improvements in bridge design. A calm and impartial examination of the fundamentals is required, by some group which will be given all the existing data without reservation and which can stay with the task till every pertinent point has been thoroughly examined.

With the full cooperation of all concerned with the design and erection of the bridge and the manufacture of the wire, representatives of the engineering mechanics section and the metallurgical division were on the bridge during the dismantling of the cables, observing the condition of the wire and taking an ample supply of samples.

The examination of samples of broken and unbroken wires, however, may throw light on only a part of the problem. A study of the much broader subject of "notch propagation" in coated or duplex metals appears to be a necessary part of the complete program.

Scope of Bureau Metallurgical Research. The examples mentioned above show that the work of the metallurgical division touches many points ranging from pure theory to engineering practice. In this account nearly every metal in the periodic table has been mentioned. It may seem that the work is too widely scattered and that concentration would be desirable. As a matter of fact, the number of projects under study is less at the end of the fiscal year than it was at the beginning, and many worthy projects that have been suggested have been left untouched for lack of funds and staff to deal adequately with them without neglecting problems already under way.

Light is thrown on almost any project from the accomplishments on other projects. The same fundamental metallurgical principles apply to practically all the projects, so that there is some advantage in a diversification of interest.

It would be impossible to do constructive work in so many subdivisions of the metallurgical field were it not for the interest and cooperation of other metallurgists and of the metallurgical industries. Close contact with the Advisory Committee, with visitors, and with the work of others through the technical societies and the metallurgical journals is essential for effective research by the Bureau, and it is hoped that this report may lead to further contact and cooperation with the readers of METALS and ALLOYS. Comments on the criticism of the program outlined herein are invited.

Observations on the Iron-Nitrogen System[*]

By S. Epstein, H. C. Cross, E. C. Groesbeck and I. J. Wymore

From the standpoint of nitriding, the constitution diagram of the iron-nitrogen system is important, mainly because it must form the basis of our understanding of the more complex system, involved in the nitriding of special alloy steels. The low nitrogen side of the diagram is of general importance since it is believed that comparatively small amounts of nitrogen may materially affect the mechanical properties of iron and steel. It has been suggested that temper brittleness and blue heat phenomena in iron may be due to nitrogen, the solubility of which in iron appears to be appreciable at 500–550° C. and much less so at room temperature. The accurate determination of the high nitrogen side of the diagram is extremely difficult.

Fairly homogeneous iron-nitrogen alloys of very low nitrogen content can be obtained by melting iron in an atmosphere of nitrogen, but alloys of high nitrogen content cannot be produced in this way, even under very high pressures of nitrogen. The usual method of introducing nitrogen into iron is by diffusion into hot solid iron. Molecular nitrogen does not diffuse appreciably, so nascent nitrogen, such as is formed in "cracking" ammonia gas by passing it over hot iron, is necessary. Alloys containing a maximum of about 11 percent nitrogen may thus be obtained. The nitriding is, however, not uniform, but takes place by the formation of several distinct layers of different iron-nitrogen compounds, so that the nitrogen content of even a very small nitrided particle may vary discontinuously from a small fraction of a percent near the center to about 11 percent at the surface. These layers are very unstable, nitrogen gas being liberated upon heating to temperatures as low as 300° C. and the gas evolution increasing rapidly at higher temperatures. The changing nitrogen content and the obscuring of the transformation points, through the heat effects produced by the gas evolution, contribute to the difficulties of determining by thermal analysis and interpreting the critical points in such specimens.

An account is given in this paper of thermal analysis, microscopic examinations and X-ray diffraction analysis made on a number of electrolytic iron and aluminum-molybdenum steel specimens nitrided at various temperatures. The purpose of the investigation was to resurvey some portions of the iron-nitrogen system as determined previously by other workers. In a system beset with so many difficulties final conclusions can not be hastily drawn, for some of the interpretations of the data are matters of opinion. No claim whatsoever is made that in this paper the matter of the iron-nitrogen constitution diagram is completely settled.

From the data obtained and with the two existing diagrams of Sawyer and Fry as a basis, a modified iron-nitrogen constitution diagram has been tentatively drawn. This diagram is not to be considered as an "equilibrium" diagram, as the term is generally used. The thermal analyses appeared to confirm those of Sawyer, which indicated that there are two temperature horizontals on the high nitrogen side of the diagram, although the upper horizontal was indicated by microscopic examination to represent a peritectoid reaction and not a eutectoid transformation as Sawyer supposed. In the microstructure three iron-nitride layers were observed, whereas Fry had noted only two. The outer, intermediate and inner layers have been designated as Fe_2N, Fe_4N and Fe_6N, respectively. In X-ray analyses a hexagonal close-packed pattern and indications of a face-centered cubic pattern, ascribed to gamma iron containing nitrogen in the lattice, were obtained. According to the microstructure of the layers it appeared probable that the face-centered cubic lattice was due to the inner layer, Fe_6N; this is not in agreement with the interpretation of X-ray data by Hagg and other investigators who ascribe the face-centered cubic lines to Fe_4N, apparently on the basis of Fry's diagram wherein only two nitride layers, Fe_2N and Fe_4N, are assumed. The aluminum-molybdenum nitriding steels, nitrided at the usual nitriding temperatures, contained only one layer and showed a hexagonal close-packed pattern.

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[*] **Technical Abstract of a paper to be published in the *Bureau of Standards Journal of Research*.**

X-Ray Metallography in 1929*

By George L. Clark[1]

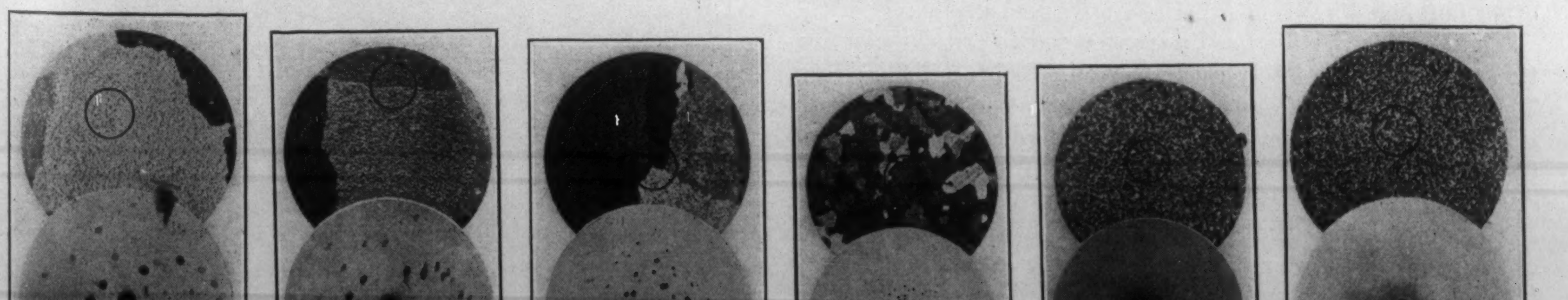
7. The Determination by X-rays of Grain Size, Internal Strain, Grain Orientation and Other Properties in Metals and Alloys

1. The Scope of X-ray Diffraction Information. In the subject-matter thus far developed in this paper in Parts I, II and III, particular application of fundamental principles has been made to the analysis of crystalline constitution or ultimate structure. It has been shown that such analyses of metals and alloys may involve the use of single crystals or of specimens composed of many fine grains usually in random orientation. The various experimental methods employing either single crystals or aggregates have been outlined in Section 4, Part II, page 63. It has also been indicated that numerous other types of information concerning metals and alloys besides ultimate crystalline structure may be obtained from the interpretation of the X-ray diffraction patterns. It is at once apparent that a whole series of specimens may give identically the same known crystal pattern characteristic of body-centered cubic α-iron, and yet from the standpoint of *practical behavior* these specimens may vary enormously. If, then, X-rays told us only that all the specimens were α-iron, they would perform a notable service but fall far short of the greatest usefulness. Fortunately, by means of these rays it is possible to make fundamental and subtle distinctions between the specimens, which all have the same unit crystal cell, far beyond the powers of any other testing agency, and thus scientifically to account for actual behavior in service, and to enable rational establishment of manufacturing processes which will assure a desirable combination of properties in terms of a desirable structure. It is this information concerning grain size, internal strain, fabrication, heat treatment, etc., which is the newest contribution of X-ray science and at the same time the most important from the actual industrial point of view. These subjects occupy the remaining parts, IV and V, of this paper. In this part consideration will be given to the fundamental interpretation of X-ray patterns in terms of some of these properties, while Part V will be devoted largely to actual examples and achievements of the X-ray method in metallurgical industry.

2. Grain Size. *a. X-ray Evidence of Grain Size.*—In Figures 18 and 23 (Part II) are shown the X-ray diffraction patterns for two extremes of grain size of α-iron, respectively, a single crystal grain and a random aggregate of very small grains. The former is distinguished by a symmetrical array of Laue spots, the latter by a series of concentric, continuous Debye-Scherrer rings. Both patterns are definitely characteristic of crystalline α-iron and, in addition, each characterizes a particular condition of grain size. Of course there may be every possible gradation in grain size between the extremes and also extending to smaller grain sizes in the colloidal range than represented by Figure 23. The Laue photographs, taken several years ago by Czochralski of specimens of aluminum with 1, 2, 5, 120, 2000 and 1,000,000 grains in the path of the X-ray beam defined by a pinhole, are still a classical contribution. These are reproduced in Figure 50. Since polychromatic rays from a tungsten target were used, a typical Laue pattern with spots lying on ellipses represents the single grain. As the number of grains increases the elliptical loci become entirely obscured, and the spots become smaller and "peppered" around the central undiffracted beam. If a more nearly monochromatic beam had been used the spots would have concentrated for the very small grain sizes into the concentric rings characteristic of powders. This tendency is observed even when the diagram is still distinctly spotted as illustrated in Figure 26 (Part II). In general, it may be stated that specimens with grains larger than 10^{-3} cm. in diameter produce a fairly uniform peppering of diffraction spots which grow larger and fewer in number as the grain size increases or the number of grains in the path of an X-ray beam of constant cross-section decreases. In the region of 10^{-3} cm. these spots begin to lie on Debye-Scherrer rings if the Kα-doublet of the radiation is present so as to exceed all other rays in intensity (that is, approaching monochromatic rays). As the size still further decreases, the spots lying on rings decrease in size and increase in number until individual spots can no longer be distinguished and the diffraction rings apppear of continuously uniform intensity and have maximum sharpness. There is a range of particle sizes between 10^{-3} and 10^{-6} cm. as limits which produce these sharp rings and which, therefore, cannot be accurately distinguished. As the grain still further decreases in size below 10^{-6} cm. into the colloidal range, the interference effects become less perfect as the number of parallel reflecting planes falls below a certain value. This manifests itself as a *broadening* of the diffraction rings, so that a measurement of breadth leads directly to an evaluation of grain sizes of colloidal dimensions, as will be illustrated later.

b. The Measurement of the Size of Submicroscopic (Colloidal) Crystals.—Since the X-ray method of evaluating particle size was first applied to submicroscopic or colloidal particles from 10^{-6} to 10^{-8} cm., this range will be considered here first.

Debye and Scherrer were the first to derive an equation connecting particle size with an experimental measurement of the breadth of interferences at points of half maximum intensities.



1 gr. 2 gr. 5 gr. 120 gr. 2000 gr. 1,000,000 gr.

Figure 50—Effect of Grain Size and Number upon Laue Patterns (Aluminum, Czochralski)

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* Part IV of an article to be published in five parts; for Part I see pages 14–17 of this publication, July; Part II, pages 57–68, August; Part III, pages 98–111, September (1929).

[1] Professor of Chemistry, University of Illinois.

The equation is

$$B_{\text{Scherrer}} = 2\sqrt{\frac{\ln 2}{\pi}} \cdot \frac{\lambda}{D} \cdot \frac{1}{\cos \theta/2} + b$$

where B is the breadth of a diffraction interference at points of half maximum intensity, λ is the wave-length, D is the edge-length of the crystal considered as a cube, θ is the angle of diffraction and b is the natural minimum breadth of the Debye-Scherrer diffraction line which is a constant depending upon the particular apparatus and size and absorption of the specimen. Scherrer first determined b by plotting measured values of B against $1/\cos \theta/2$ for a sample of colloidal gold. The straight line drawn through the points was then extrapolated to cut the ordinate axis which was the value of $b_0 = b_r$ where r is the radius of the camera. This equation served for several years though comparatively little work was done on critical experimental test. Selyakov[2] by a considerably more straightforward proof derived the equation

$$B_{\text{Selyakov}} = \frac{2\sqrt{3 \ln 2}}{\pi} \cdot \frac{\lambda}{D} \cdot \frac{1}{\cos \theta/2} + b$$

which differs from the Scherrer equation by less than 2%. W. L. Bragg[3] by remarkably simple reasoning and calculation utilizing the conception simply of n planes of thickness d arrived at the equation

$$B_{\text{Bragg}} = 0.89 \frac{\lambda}{D} \cdot \frac{1}{\cos \theta/2} + b.$$

Expressed in the same form,

$$B_{\text{Scherrer}} = 0.94 \frac{\lambda}{D} \cdot \frac{1}{\cos \theta/2} + b.$$

In 1926 von Laue[4] deduced from vector analysis a new equation which in its most general form is free from the limitations of the cubic system, and permits size evaluation in different directions and thus *shape* of a particle. In the simplest rigorous form this equation is

$$B_{\text{Laue}} = \frac{\frac{\pi}{2}\frac{\omega}{\eta}\left(\frac{r}{R}\cos^2\frac{\theta_h}{2}\right)^2}{\sqrt{1 + \left(\frac{\omega r}{\eta R}\cos^2\frac{\theta_h}{2}\right)} - 1}$$

where

$$\omega = \frac{1}{1.8} = 0.55; \eta \doteq \frac{\omega}{2\pi}(B \cos \theta/2 - 1/B)\left(\pi \frac{r}{R}\right)^2 \cos^3 \theta/2;$$

r = radius of the cylindrical specimen, R = radius of camera and θ = reflection angle. A simplified expression used with singular success by Hengstenberg and Mark[5] in determining the actual size and shape of the colloidal micelles of rubber and cellulose is

$$R\eta = 0.088\ [(b \cos \theta/2 - (1/b)\pi^2 r^2 \cos^3 \theta/2)]$$

where $R\eta$ and θ have the same significance; $b = BR$ is the actually measured breadth of the interferences, and $\eta = \lambda/4\pi ma_i$; where ma_i is the extension of the crystal particle in the direction a_i, or the magnitude which is to be calculated with all other numbers known or experimentally measurable.

The Laue derivation has been subjected to critical examination and extension lately by Patterson,[6] Brill[7] and the writer. The necessary conditions for the Laue equation are for absorption in the crystal powder which is negligibly small, for completely random orientation, for particles of the same form and size, for undistorted lattices, and for known crystal structures. Patterson extended the theory to the case where the particles have different sizes and showed that the sizes must have a Maxwellian distribution. Without information concerning the distribution function the average particle size cannot be determined. Brill extended the theory to the case of substances opaque to X-rays and derived corrections for absorption, and for the overlapping of the α-doublet interferences. The writer has extended these calculations and derived the following general and rigorous formula for ma_i the extension (or size) of the crystal particle in the direction a_i:

$$ma_i = \left[\frac{3.6\,\lambda \sin^5 \theta/2 \tan \theta/2RB}{4d(B + \pi r \sin\theta \sin\theta/2)(B - \pi r \sin\theta \sin\theta/2)}\right]$$

where $B = b - \delta/3$ (b = measured width of interferences at points of half maximum intensity, δ = separation of the α-doublet; d = lattice constant from known crystal structure; and the other symbols have the same significance as noted before.

c. Microphotometers.—It is virtually impossible to measure with any degree of accuracy, visually or microscopically, the breadth of a diffraction interference on a photographic film, since the edges are usually diffuse. Consequently, it is essential to have some method of converting a pattern into a curve with the diffraction lines represented by peaks whose breadths at half maximum intensities may be easily measured. The microphotometer is an instrument for converting a photographic spectrum automatically into an intensity curve. A very constant source of light is defined by a slit over which the film is slowly driven. Beyond the film is a sensitive thermocouple or photoelectric cell connected with a galvanometer whose deflection is proportional to the amount of light transmitted through the film. The motion of the galvanometer mirror is registered on a sensitized paper on a rotating drum; the result is a continuous curve with peaks marking the diffraction maxima. The most familiar type of microphotometer is probably the Kipp and Zonen made in Delft, Holland. Figure 51 shows an excellent instrument designed by the writer and R. L. Davidson. Figure 52 shows a typical microphotometric curve for a platinized asbestos catalyst upon which the measurements of breadth of diffraction maxima are made. Such an instrument has become an indispensable part of the equipment of an X-ray laboratory which is concerned with quantitative measurements. It is obvious that the curves enable an accurate estimation of *position*, or θ, and of intensity (height), as well as particle size from breadth.

d. Metallurgical Examples of Determination of Submicro-

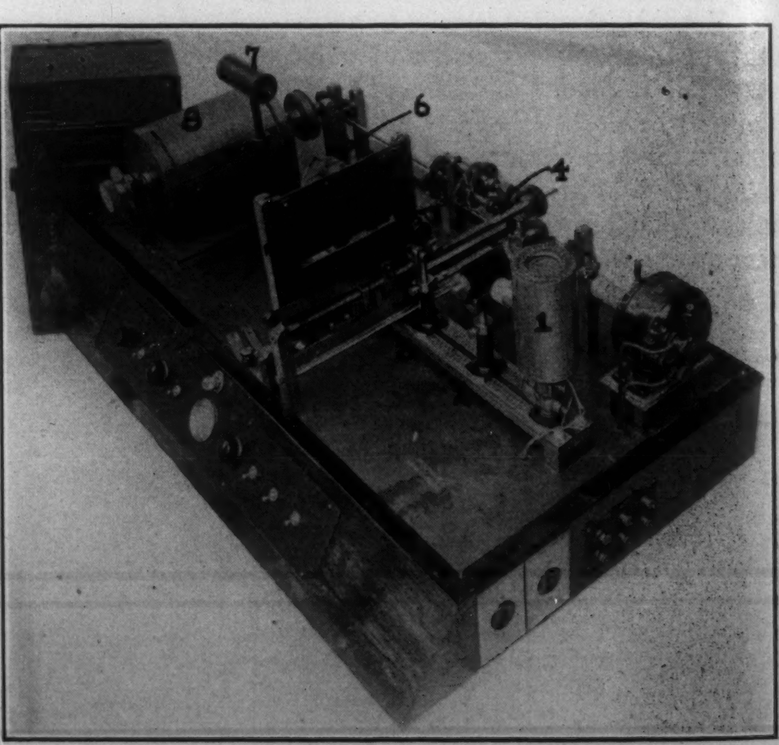

Figure 51—Microphotometer for Accurate Measurements on X-ray Films. 1, Constant Source of Light; 2, Slit; 3, Lens; 4, Driving Screw for Slow Movement of Film Holder; 5, Film Holder for Moving over Narrow Beam of Light; 6, Sensitive Silver-Bismuth Thermocouple Registering Intensity of Light Transmitted through Successive Positions of Film; 7, Galvanometer Lamp (galvanometer not shown); 8, Rotating Drum for Sensitized Paper (cover removed) Registering Deflections of Galvanometer Mirror

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[2] *Repts. of Phys. Tech. Roentgen Inst. and Leningrad. Phys. Tech. Laboratory*, **1926**, 67.

[3] Private communication.

[4] *Z. Krist.*, **64**, 115 (1926).

[5] *Ibid.*, **69**, 271 (1928).

[6] *Ibid.*, **66**, 637 (1928).

[7] *Ibid.*, **68**, 387 (1929).

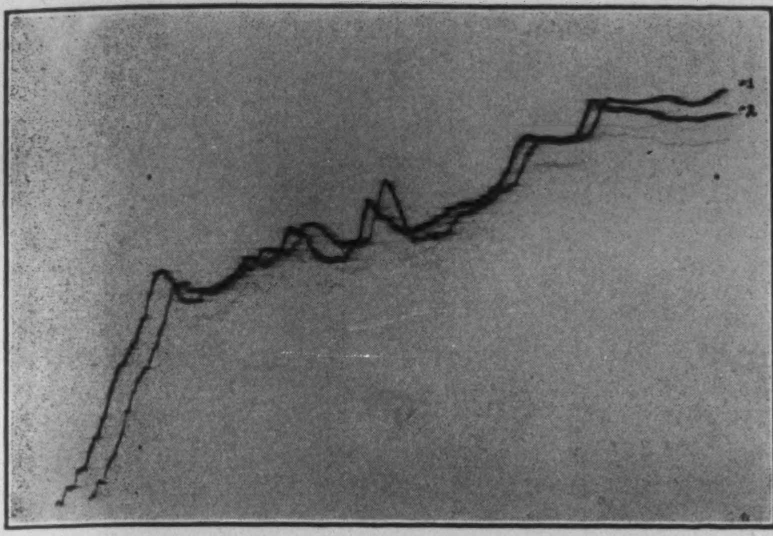

Figure 52—Photometric Curves of Powder Diffraction Patterns for Two Platinized Asbestos Catalysts (Contact Sulfuric Acid Process)

scopic Grain Size.—Brill has compared the Scherrer and Laue equations for several samples of iron as follows:

	Scherrer	Laue
Fe from Fe_3O_4	2.3×10^{-6}	2×10^{-6}
Heated 10 hrs. at 1000°	4.2×10^{-6}	∞
Fe from carbonyl I (300°)	7.7×10^{-7}	1×10^{-6}
II	6×10^{-7}	9×10^{-7}
III	1.0×10^{-6}	1.1×10^{-6}
IV	1.2×10^{-6}	1.0×10^{-6}
(1000°)	3×10^{-6}	∞
Electrolytic iron	2.3×10^{-6}	2.3×10^{-6}

There is thus general agreement except for large sizes where the Scherrer equation fails. It is adapted only for small particles in the range and for heavily absorbing substances. Brill has employed lead glass tubes for substances of small absorbing power in order to meet the condition of nearly complete absorption, the diffraction taking place only superficially.

The particle size of martensite has been determined several times, Westgren finding 10^{-7}, Wever 10^{-6}, and Selkjakov 2×10^{-6} cm. Clark and Brugmann in studying the structure of case-hardened steel, which is martensite and troostite very largely, estimated a particle size of 10^{-7}.

One of the most important and interesting applications is that of particle size of metal catalysts. Clark, Asbury and Wick[8] were the first to make a study of particle size as related to the activity of finely divided catalysts. They measured photometrically the line breadths of diffraction spectra from a number of nickel catalysts with identical crystal lattice type and dimensions, prepared in various ways and differing widely in catalytic activity in hydrogenation and dehydrogenation processes. Most of these catalysts consisted of particles larger than 10^{-6} cm. so that the Scherrer equation did not apply. In general, increase in activity and decrease in particle size did not run parallel as might be expected. There is a more definite relationship for platinized-asbestos catalysts used in the contact sulphuric acid process. Levi[9] has made several measurements of particle size of the platinum family of metals from the photometered X-ray diffraction spectra, with the result that granules of platinum were 12 to 29 times as large on the side as the unit crystal cell; palladium 13 to 29, rhodium 6, iridium 4, ruthenium 7 to 8, osmium 6 (latter two hexagonal).

Some of the most interesting particle size measurements have been made on such non-metallic substances as carbon-black, pigments, colloidal suspensions, rubber, cellulose, etc. The question is raised as to where the discontinuity between crystalline and amorphous appears, and whether there is any evidence of amorphous metal at grain boundaries, etc. It is reasonable to suppose that diffraction lines may become so broad that they will coalesce and produce the effect of general fogging of the film such as an amorphous material would be expected to act. From the evidence of carbon black an amorphous state may show transition to crystalline as judged by changes in physical or chemical properties, while the X-ray pattern is unchanged at first, simply because the crystalline planes are still too few and too distorted to enable sharp interference. It must be realized that temperature oscillations of atoms in a lattice and also distortion both have the effect upon diffraction lines of broadening them just as small grain size. These factors must be known, therefore, before adequate interpretation is possible. There is no positive X-ray proof of the amorphous cement theory of metal aggregates in spite of numerous attempts. Nor can it be said that the theory has been disproved though it seems unlikely.

e. Particle Size Measurement in the Microscopic Range.—A method of evaluating grain size to supplement and check microscopic measurement of grains of the order of 10^{-3} to 10^{-2} cm. in diameter has long been needed, particularly if some information can be obtained about grains below the surface of a polished specimen. X-ray patterns are now filling this requirement. It has been demonstrated already that with grain sizes of 10^{-3} cm. or larger, the diffraction interferences are no longer uniform and continuous circles or lines. These interferences show individual spots and as the size increases the Debye-Scherrer rings disappear and a uniform "peppering" such as is shown in Figure 53. The size of the spots depends upon the divergence of the primary X-ray beam, the size and shape of the focal spot on the target of the X-ray tube and the extent of the crystal in the plane of the reflecting face. Consequently, the size of the interference spot on the photographic film from a grain increases with increasing grain size so long as the cross section of the crystal perpendicular to the ray to be reflected is smaller than the cross section of the impinging bundle of rays. Mark and Boss[10] have shown a linear relationship between the size of interference spots for particles between 10 and 100μ (10^{-3} to 10^{-2} cm.) and the grain size measured microscopically. The slope of the straight lines depends upon the experimental conditions and apparatus but, once known, grain sizes may be directly read off for any specimen from a measurement of the interference spots. It is essential that the grains should have uniform size since otherwise the X-ray measurement will give the average only of the largest particles, the small particles producing no individual sharp interferences. The effect of size distribution is very clearly demonstrated in Figures 54*a* and *b*. Two specimens of silica with the same average particle size as prepared and measured by Drinker and Hatch at the Harvard School of Public Health were subjected to X-ray analysis by Aborn and Davidson in the laboratory established by the writer at the Massachusetts

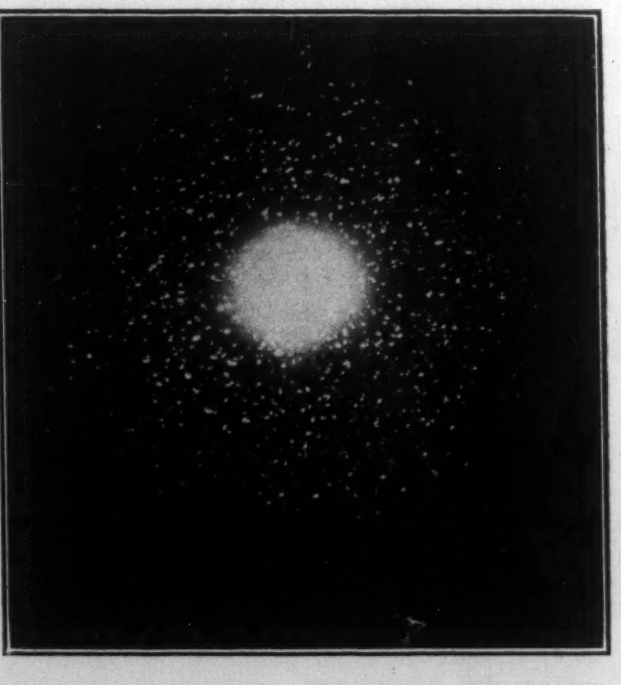

Figure 53—Pinhole Pattern for Transformer Steel Showing "Peppering" of Spots Rather Than Diffraction Rings on Account of Relatively Large Grain Size

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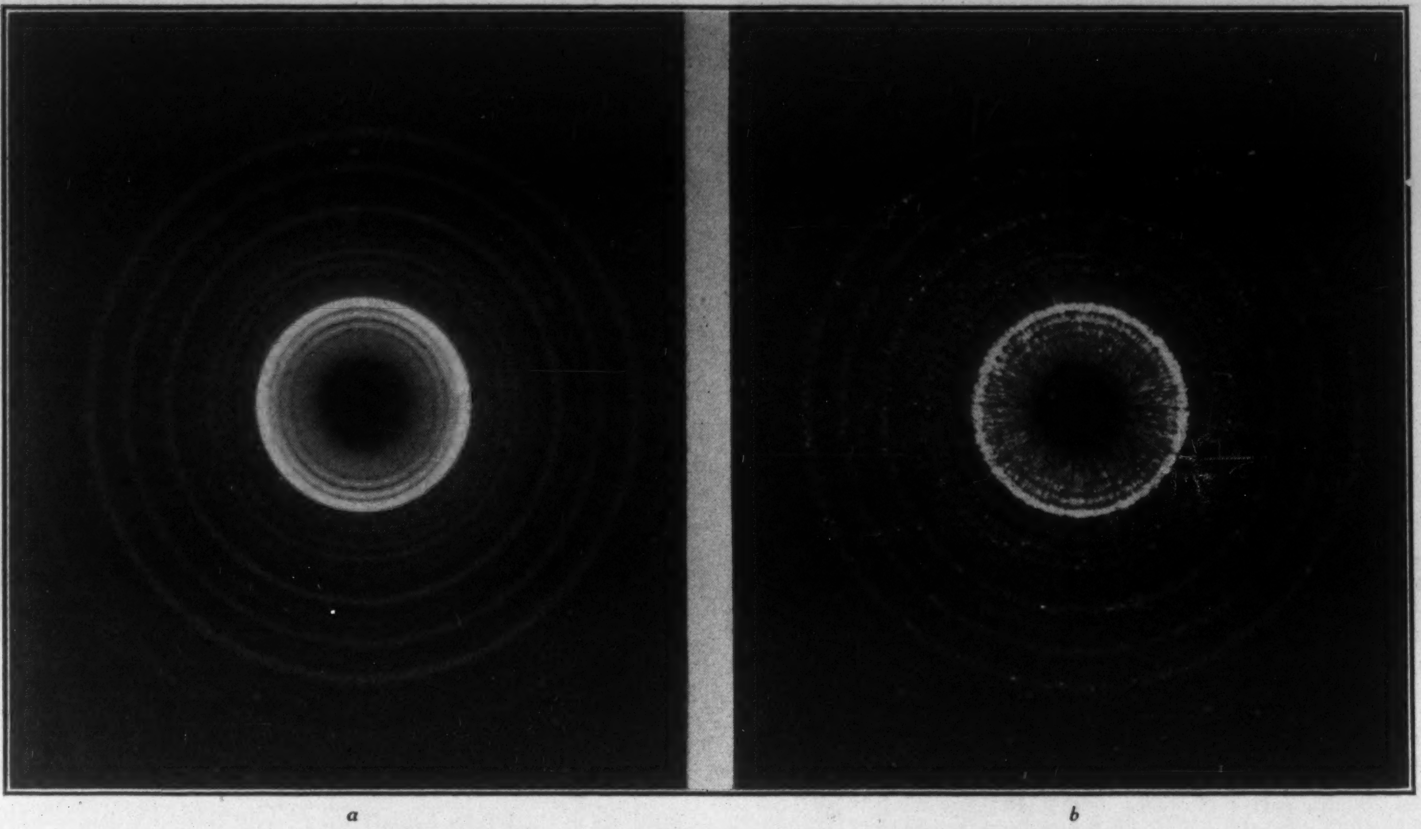
[8] *J. Am. Chem. Soc.*, **47**, 2661 (1925).

[9] *Atti accad. Lincei* (6), **3**, 91 (1926).

[10] Mark, "Materialprüfung mit Röntgenstrahlen," Berlin, **1927**, page 299.



a
Average size 4.4 μ
Distribution (standard deviation) 1.341

b
4.5 μ
2.166

Figure 54—Pinhole Diffraction Patterns for Two Samples of Silica with Nearly the Same *Average* Particle Size but Differing Widely in the *Distribution* of Sizes

Institute of Technology, with the results shown in the figure. The difference is remarkable. In 54*a* the deviation from the average was very small, while in 54*b* it was large. Without a knowledge of the fact that the average particle sizes were the same, and of the distribution, the mistake would be made of assigning a considerably larger particle size to 54*b* in which the large grains producing individual interferences are balanced by grains too small to produce distinguishable spots. Microphotometric curves are reproduced in Figures 55, 56 and 57, respectively, for grain sizes of 4.4μ standard deviation 1.34 (Figure 54*a*); 4.5 μ, standard deviation 2.116; and 36μ, standard deviation 1.28. These were made by turning the film around an axis so that one of the diffraction circles was continuously registered. It is obvious that there are no equations comparable to those for colloidal particles for calculating particle size of large grains from a measured quantity such as diffraction interference breadth. Hence the microphotometric curves were measured, including number of peaks per unit length, average height of peaks, area per peak and the total area under peaks per unit length. When for specimens with nearly the same size distribution the last named quantities are plotted on log paper against average particle size, the points lie on a straight line. For specimens with widely different distribution but the same average size the points do not lie on this line. This work on silica is of great importance in laying the foundation for further work on metal grain sizes. It is evident that considerable care and skill is required in deducing accurately grain size for the region in question.

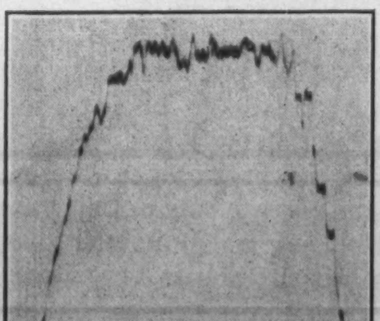


Figure 55—Photometric Curve of One of Diffraction Rings of Figure 54*a*

A special committee consisting of Messrs. Dix, Lucas, Rawdon and C. H. Davis, chairman, has recently submitted to the American Society for Testing Materials a set of beautiful photomicrographs illustrating standard grain sizes of brass from 0.010 to 0.200 mm. These are reproduced in the 1929 preprint of the Report of Committee E-4. To parallel the microscopic work these samples are now being subjected to X-ray study in the writer's laboratory in an effort to standardize X-ray patterns as a means of evaluation of grain size.

f. Examples of Measurement of Size of Microscopic Particles.—It is needless to point out the very great importance of grain size in terms of practical behavior of commercial materials. Practically all annealing operations following mechanical work involve grain growth. Magnetic permeability and hysteresis loss in electric steels are certainly dependent upon grain size. The life of electrical contact points is a function of optimum grain size. Even the enameling of steel, corrosion, electrodeposition and numerous other phenomena depend upon grain size. Many of these will be illustrated in Sections 8 and 11 of this paper, devoted to heat treatment and to practical applications of X-ray methods to commercial metals. The control of grain size in metallurgical products is one of the great achievements of the science.

3. Orientation of Grains. Many research and practical problems arise in which a knowledge of orientation of crystal planes in a single metal crystal or of single grains in an aggregate are highly desirable. It has been demonstrated previously that the X-ray goniometer is a powerful method of ascertaining orientation. One especially excellent

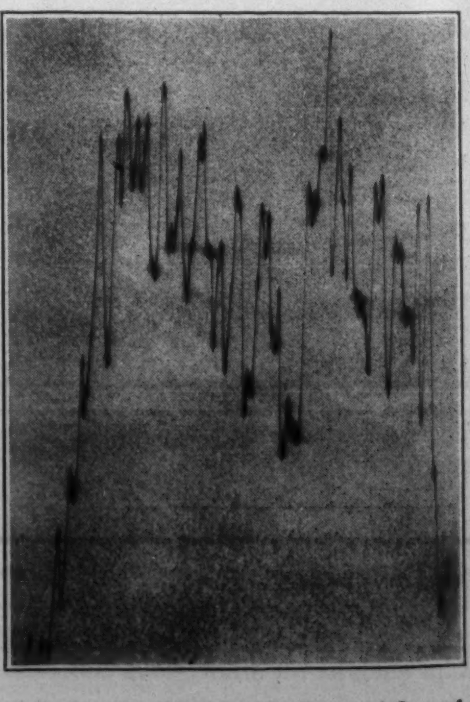


Figure 56—Photometric Curve of One of Diffraction Rings of Figure 54*b*

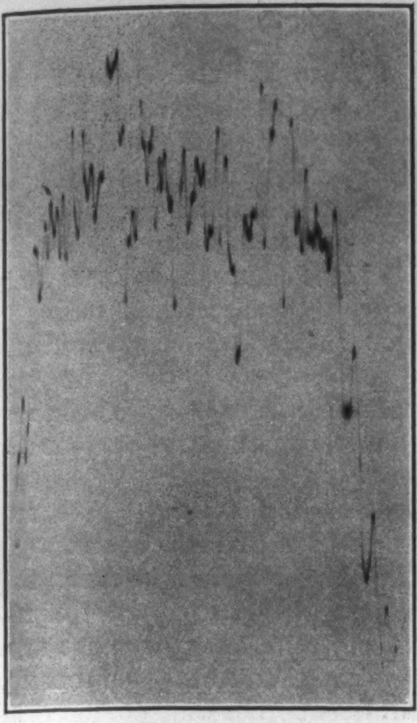


Figure 57—Photometric Curve of Diffraction Ring of Silica Sample with Average Particle Size 9 Times as Large as Samples in Figure 54, but with Small Standard Deviation

instrument has been devised by Weissenberg for such problems. Single metal crystals are made frequently by cooling a melt in a quartz tube by extremely slow and careful cooling, as first devised by Prof. Bridgman. Obviously, no planar faces are developed and recourse must be taken to goniometric establishment of orientation of planes with respect to one direction or another before physical data may be properly interpreted. There are frequent references to X-ray goniometry of this kind in the literature, especially with reference to the presence or absence of twinning. Again, a strip or sheet of metal may be polycrystalline and yet have certain properties dependent upon just how the individual grains (of course large) are oriented with respect to the surface. This is especially true of electric or magnetic properties, which may differ widely for two specimens, say, of silicon steel, with the same apparent grain size and general structure. In this case the Laue method of crystal analysis may be employed. A great service has been performed by M. Majima and S. Togino[11] in making Laue photographs for body-centered and face-centered cubic metals in every possible and known orientation with respect to the X-ray beams. It is necessary, therefore, only to compare a Laue pattern for a grain in a sheet, to the surface of which the X-ray beam is perpendicular, with the standard patterns in order to establish easily the orientation of the lattice planes of the grain in question with respect to the surface.

4. **Internal Strain.** Many metal structures fail because of gross defects which may be detected readily by radiographic examination (Part I). But many metal objects may appear radiographically perfectly sound and still fail. The cause here is far more deep-seated and is concerned with residual internal strain or lattice plane distortion. Strain in transparent objects is readily ascertained by interference colors when examined in polarized light. In this manner glass apparatus is tested. Dirigible models of transparent celluloid have been studied under all conditions of stress. The writer has even detected strain in linseed oil and patent leather films in this way. But for opaque objects such as metals the method is precluded. The use of gauge marks for detecting strain in metals is well-known. For example, the diameter of a cylinder of metal is very carefully measured. Successive layers from the inside of the cylinder are then removed on a lathe and the changes in the outside diameter with the relief of strain observed. There are many modifications of this technic which have been widely employed but there are serious objections and limitations. In the first place the dimensional changes may be too small to measure accurately. Again, the direction of the strain may be such as to be missed entirely by the gauge mark method. In all of metallurgy there has been no problem which has so urgently required an adequate method. To the detection and even quantitative estimation of internal strain X-ray diffraction science has made a great contribution, although the application still requires much fundamental research and standardization.

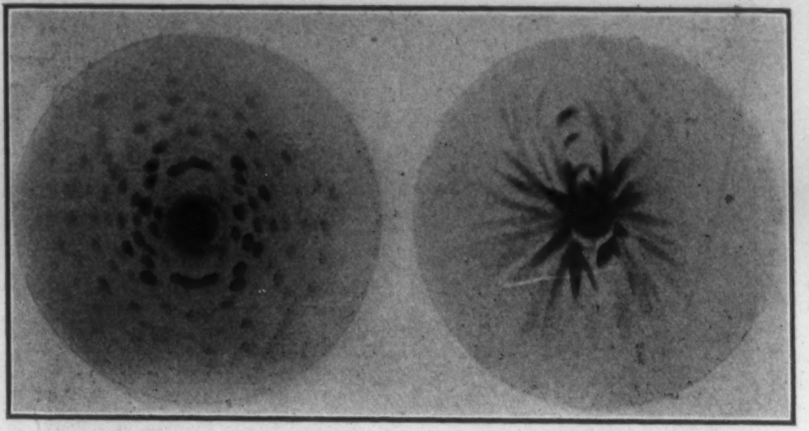


Figure 58—Effect of Bending Distortion upon Laue Pinhole Pattern of Single Gypsum Crystal (Czochralski)

Figure 58 shows what happens to the Laue diffraction pattern of a single crystal (gypsum) when it is bent. The spots are elongated to radial streaks or "asterism striations." Any pattern, even for a polycrystalline material which shows these radial streaks, is an indication of internal strain. The crystal planes are distorted so that reflection takes place as though cylindrical mirrors had replaced plane mirrors. Figure 59 shows how a strain pattern can be synthesized by loading successively a strip of iron while the exposure is made. Even under the elastic limit there is clear evidence of strain; at higher loads slipping on planes occurs and rupture accompanied by fibering of the metal in many cases. Figure 60 shows the strained condition of a block of cast steel which has been rapidly chilled. The distribution of strains of a large casting determined solely by X-ray patterns is shown in Figure 61. The world-wide interest in this figure, since its original publication nearly three years ago, is an interesting sidelight upon the value of this method in affording information heretofore impossible.

Internal strain also manifests itself by a broadening of the diffraction lines for powder patterns. In other words, interference is less sharp for distorted or bent planes just as is true for a very few planes (colloidal particles). This same phenomena occurs also at higher temperatures where the thermal vibrations of the atoms caused a departure from planes.

On account of the fact that strain is so important a commercial problem, several practical examples will be cited under the last topic of this paper.

8. The X-ray Analysis and Control of Heat Treatment and Recrystallization

1. **The Province of Heat Treatment.** When metals are

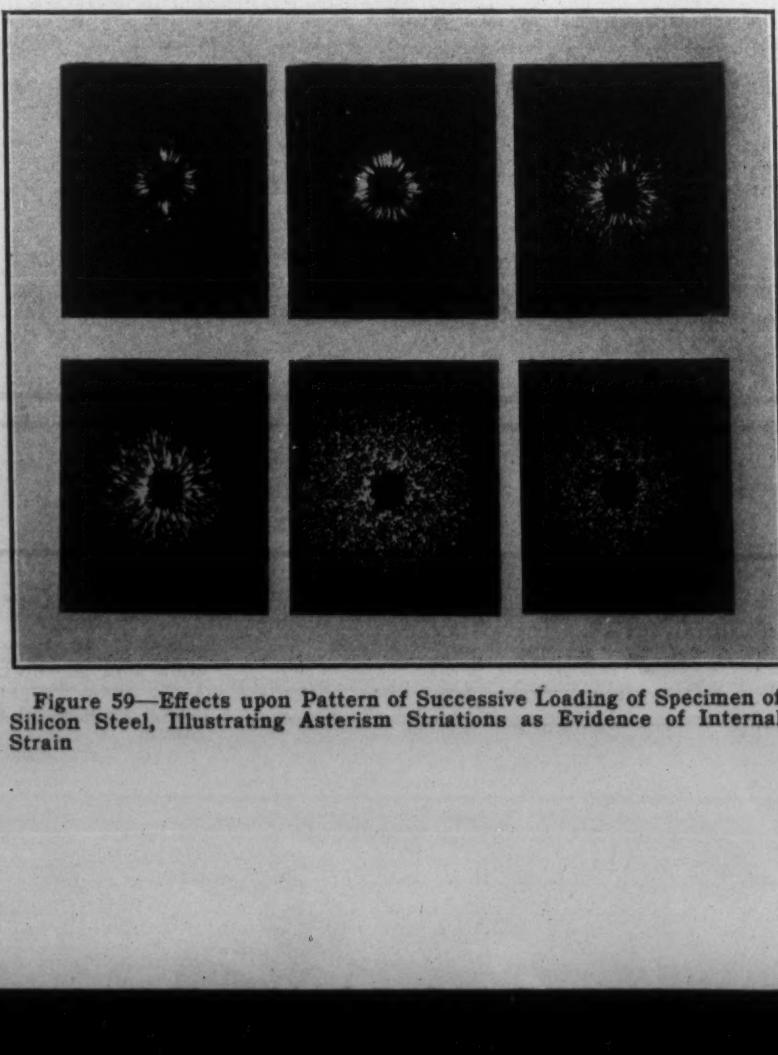


Figure 59—Effects upon Pattern of Successive Loading of Specimen of Silicon Steel, Illustrating Asterism Striations as Evidence of Internal Strain

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[11] *Sci. Papers, Inst. Phys.-Chem. Res., Tokyo,* **111,** 75–6; **126,** 259–60 (1927).

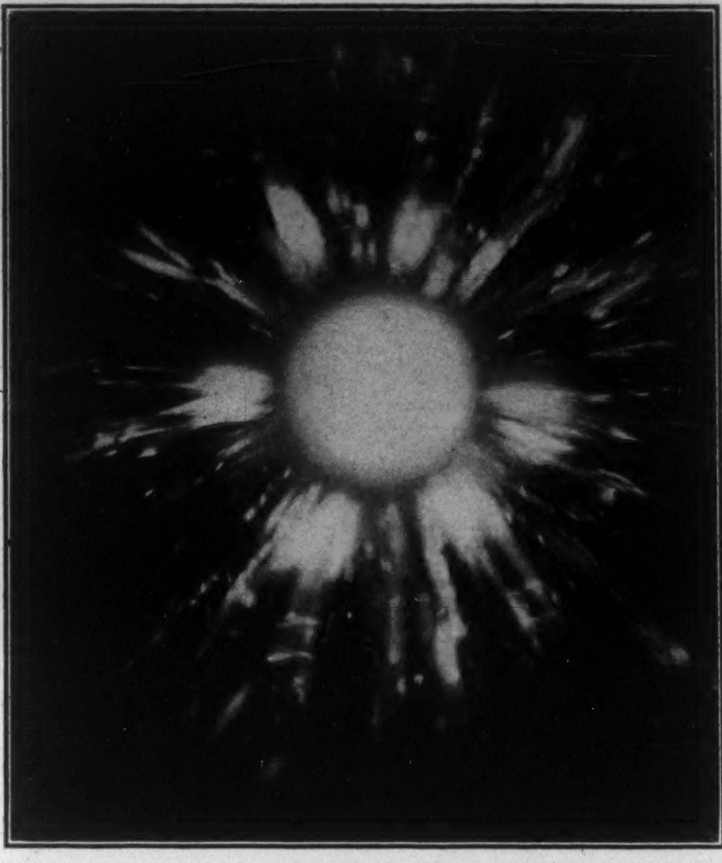

Figure 60—Irregular Radial Asterism Striations Produced by Internal Strain in a Metal Aggregate (Steel Casting)

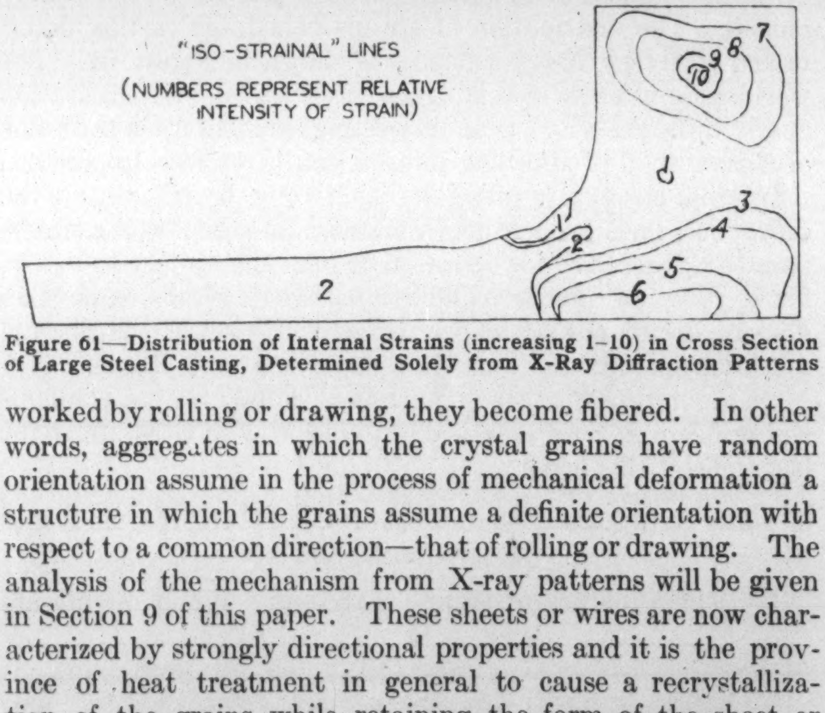

Figure 61—Distribution of Internal Strains (increasing 1–10) in Cross Section of Large Steel Casting, Determined Solely from X-Ray Diffraction Patterns

worked by rolling or drawing, they become fibered. In other words, aggregates in which the crystal grains have random orientation assume in the process of mechanical deformation a structure in which the grains assume a definite orientation with respect to a common direction—that of rolling or drawing. The analysis of the mechanism from X-ray patterns will be given in Section 9 of this paper. These sheets or wires are now characterized by strongly directional properties and it is the province of heat treatment in general to cause a recrystallization of the grains while retaining the form of the sheet or wire, so that a random, non-directional orientation is again obtained as is absolutely required, for example, in forming steels. Again internal strains introduced by rapid chilling in castings, etc., are relieved by heat treatment. The X-ray method finds powerful practice use in discovering just how completely the fiber structure or the internal strain has been removed. In its sensitiveness as such a control method it far transcends the microscopic or other physical tests.

It is the purpose of the present section to consider in a more quantitative manner the mechanism of recrystallization during heat treatment of single relatively pure metals, principally aluminum, silver and copper. The information which has been derived from X-ray researches, chiefly by Glocker, Kaupp and Widmann,[12] on these metals is astonishing in its scope.

2. Fundamental Studies of Pure Metals. Aluminum, silver and copper all crystallize on the face-centered cubic lattice. It would be expected therefore that these sheets are annealed. The first expectation is fully borne out by the analysis of the X-ray diffraction patterns of the fibrous sheets. In the process of rolling of the face-centered metals the grains orient themselves so that a (011) plane is parallel to the rolling plane and a [112] direction parallel to the direction of rolling.[13] But the prediction that aluminum, silver and copper will recrystallize during annealing of rolled sheets in the same way is far from true. It is this remarkable difference which has been discovered wholly by the X-ray method; thereby some metallurgical enigmas have been solved.

3. Heat Treatment of Cold Rolled Foils. There are three possible effects of heat treatment of cold-rolled foils: (1) the directed orientation of grains is completely lost and the new grains are in random arrangement from the outset of recrystallization; (2) between the states of fiber structure and final random arrangement there is an intermediate step consisting of a directed arrangement different from that produced in rolling, which goes over into the random type of temperatures in the neighborhood of the melting point; (3) the new recrystallization or intermediate directed orientation persists to the melting point.

a. Recrystallization of Aluminum Sheet.—At all degrees of rolling, even up to 98 percent reduction, aluminum recrystallizes with a random orientation of grains. Heating for 15 minutes at 265° C. does not destroy the fiber pattern of the rolled sheet (Figure 62) but at 275° C. or above this is lost. The pattern consists now of concentric rings with a spotted appearance indicative of a random arrangement of larger grains (Figure 63). This is the type of structure which might be generally expected, and for all the metals with degrees of rolling below 90 percent reduction, including silver and copper, this is observed. Aluminum thus represents the first of the above alternatives.

b. The Recrystallization of Silver.—Glocker[14] was the first to observe that with strongly rolled silver (97 percent) (Figure 64) the recrystallization did not take place with chaotic arrangement of grains, but with a new crystallographic orientation with the (113) planes in the plane of rolling instead of the (001) planes as in the original rolled structure. The diffraction pattern for this new directed crystal orientation is shown in

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[12] *Z. Physik*, **45**, 200 (1927); *Z. Metallkunde*, **17**, 354 (1924); Glocker, "Materialprüfung mit Roentgenstrahlen," Berlin, **1927**, page 332.

[13] A second orientation of (001) and [100] and the possibility that in aluminum the primary orientation may be (135) and [355] are complications which are of minor importance in the present discussion.

[14] *Z. Physik*, **31**, 410 (1925).

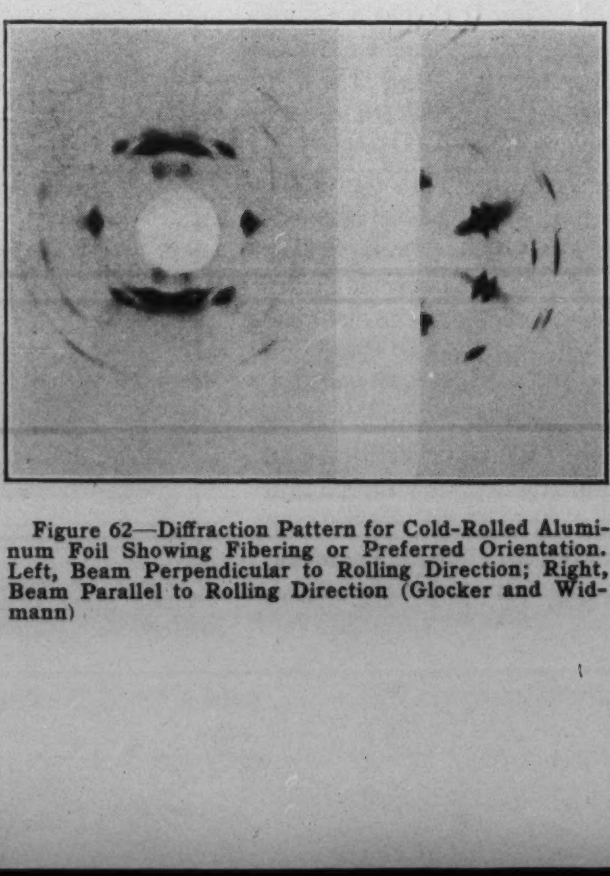

Figure 62—Diffraction Pattern for Cold-Rolled Aluminum Foil Showing Fibering or Preferred Orientation. Left, Beam Perpendicular to Rolling Direction; Right, Beam Parallel to Rolling Direction (Glocker and Widmann)

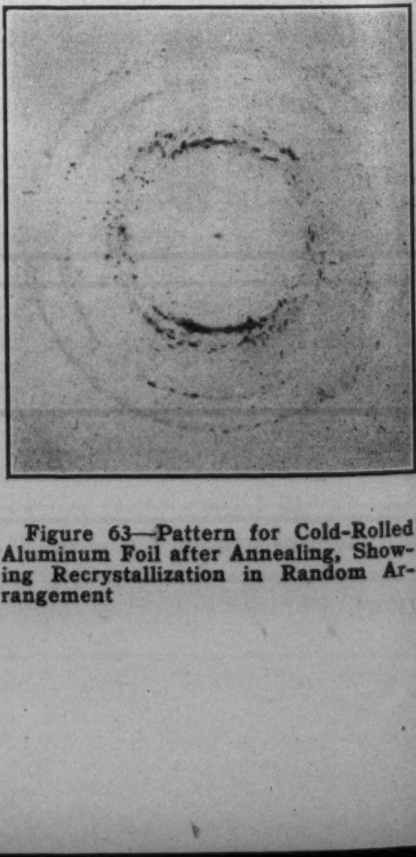

Figure 63—Pattern for Cold-Rolled Aluminum Foil after Annealing, Showing Recrystallization in Random Arrangement

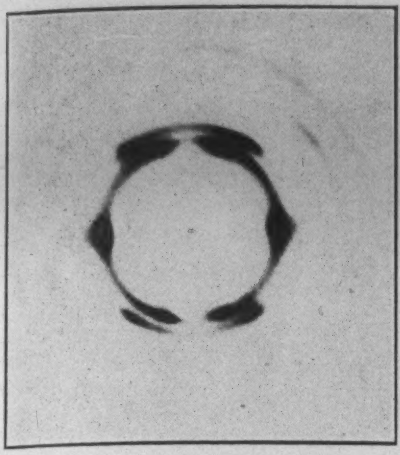

Figure 64—Pattern for Cold-Rolled Silver Foil

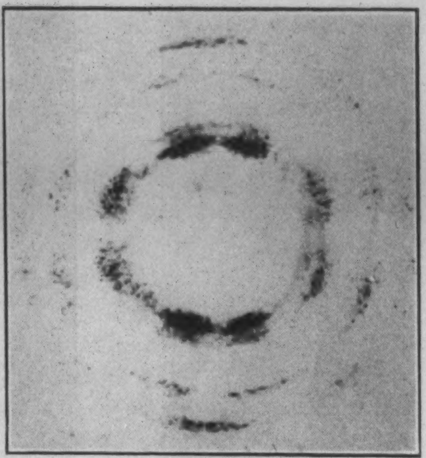

Figure 65—Pattern for Cold-Rolled Silver Foil after Annealing at 225–750° C., Showing Recrystallization in New Preferred Orientation. Random Orientation Results Only after Heating above 750° up to the Melting Point 960°

Figure 65. This structure is maintained even after 10 days or more of heating at 300° C., but at higher temperatures (rapidly at 850–900°) the random orientation results, together with a considerable increase in grain size. These facts illustrate the very important fact that long annealing at low temperatures does not necessarily produce the same effect as annealing for a short time at high temperatures, as is so often believed and practiced in metallurgical circles.

The sequence of events during recrystallization as interpreted from the X-ray patterns may also be tested and compared with the results of technological tests on tensile strength, elasticity and grain size. Widmann's data as plotted in Figure 66 show distinctly the breaks occurring with the appearance of the new directed position at 200° and with random orientation at 800°.

The very curious fact also was found that if the silver is reduced only partially in one rolling operation, is heated at 700° C., and again rolled down to final thickness, then the properties are distinctly different from those of the silver reduced in one rolling only. In the former case the X-ray patterns indicated that the sheet begins to recrystallize at room temperature. Consequently annealing produces abnormally large grains and loss of tensile strength, the metal is characterized by mixed, very large and very small grains, and is difficult to handle practically.

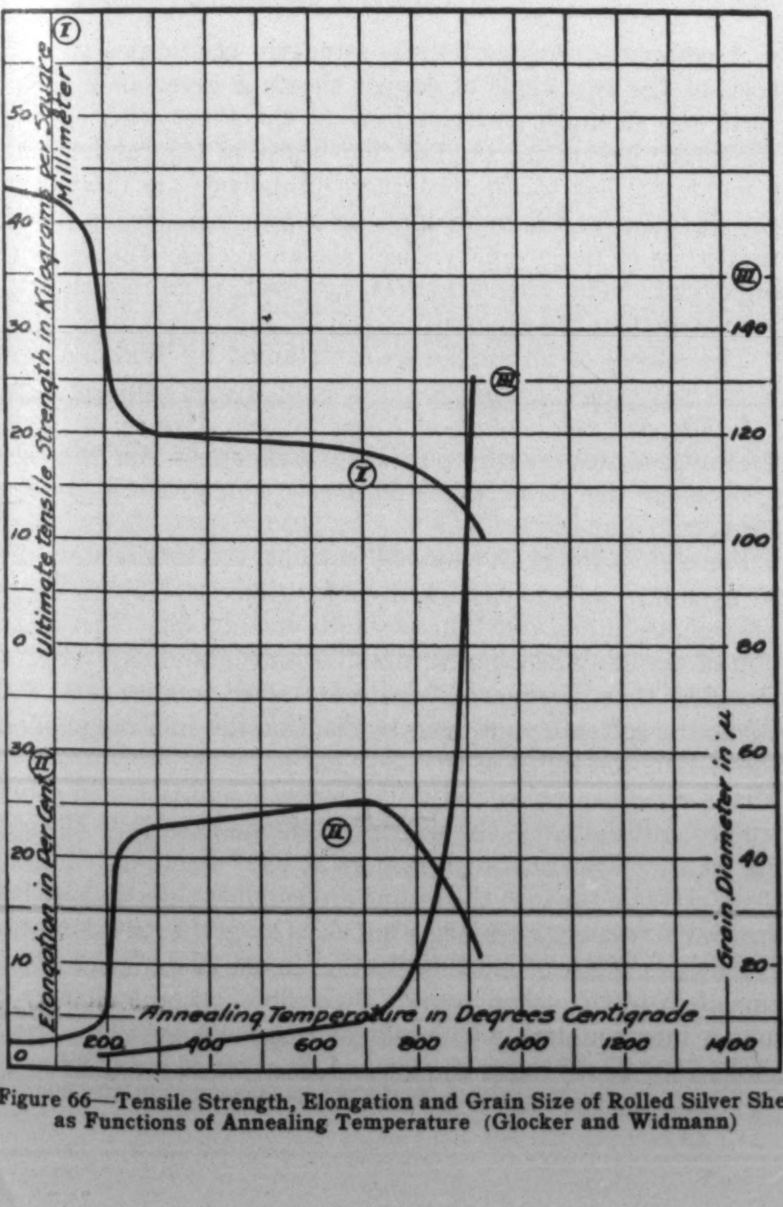

Figure 66—Tensile Strength, Elongation and Grain Size of Rolled Silver Sheet as Functions of Annealing Temperature (Glocker and Widmann)

c. Impurities Change Recrystallization Temperature.—The effects of small amounts of impurities on the recrystallization temperature of silver may be determined far more accurately from the X-ray patterns than from microscopic analysis. Widmann's studies of this subject have been fully substantiated by the present writer. In the following table are listed the data on the effects of impurities.

Element	Impurity Wt., %	Impurity Atomic, %	Recrystallization Temperature, ° C.
Pure silver	..	...	150
Copper	0.303	0.51	230
Copper	0.12	0.20	200
Copper	0.073	0.123	175
Aluminum	0.2	0.93	190
Zinc	0.119	0.195	145
Lead	0.059	0.03	145
Nickel	0.1	0.15	137
Gold	0.1	0.054	112
Gold	0.2	0.11	110
Palladium	0.1	0.10	112
Iron	0.035	0.068	110
Iron	0.055	0.107	20
Iron	0.065	0.126	20

It is clear that copper and aluminum raise the temperature while all other elements, particularly iron, lower it. Five hundredths of one percent of iron is sufficient to lower the temperature of recrystallization of silver to room temperature. Ancient as is the metallurgy of silver this fact has been discovered in the present year by means of X-rays. It is safe to conclude that silver, except of the highest purity, always has contained at least this trace of iron. Why then has not recrystallization served to ruin, practically speaking, cold-rolled silver articles? The answer is, that copper also is universally present and in amounts of 0.1 percent or less completely compensates for the powerful effect of 0.05% iron. In the same way aluminum compensates for gold which also lowers the recrystallization temperature of silver. It is interesting to note, however, that the temperature of 150° for pure silver does not hold for the very purest silver (considerably less than 0.0005 percent iron and 0.00002 percent lead) possible to prepare. Very pure silver recrystallizes at room temperature. Copper has little effect on grain size and on the appearance of the intermediate directed orientations of silver; iron, nickel and especially lead, increase grain size, and zinc decreases it. The recrystallization positions of grains are not so perfectly directed in the presence of the metals. Thus, for the first time is it possible to have a quantitative idea of the metallurgical importance of very small amounts of impurities. In every case addition of larger amounts has little or no effect as compared with the introduction of the first traces.

d. The Recrystallization of Iron.—Both brass and iron (body-centered cubic) behave somewhat similar to silver when rolled and annealed. For iron rolled 97 percent and heated above 600° there is an orientation so that the [350] direction is parallel to the rolling plane, while the cold-rolled metal is characterized by a [110] direction. Figures 67–72 show a series of patterns[15] for low carbon steel subjected to various heat treatments; of particular interest are the new recrystallization orientation (Figure 71) and the fact that random orientation is obtained only after heating above the upper critical point (Figure 72). Silver, brass and iron, therefore, represent the second of the three recrystallization mechanisms.

e. The Recrystallization of Copper.—When strongly rolled copper (99 percent) is annealed a new phenomenon is observed. The recrystallization structure shows a new orientation of

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[15] Kindly supplied by N. F. Goss of the American Steel and Wire Co., Cleveland.

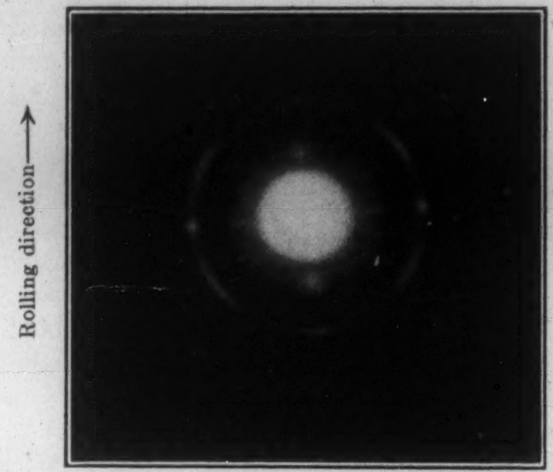

Figure 67—Pattern for Hard-Rolled Steel Shim Stock, 0.002 in. Thick, Showing Fibering with [110] Direction Parallel to Rolling Direction (Goss)

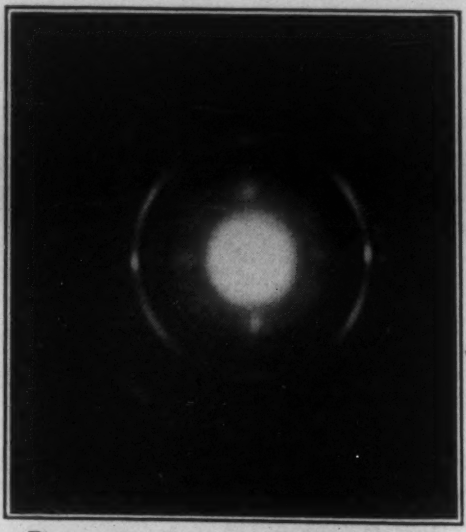

Figure 68—Same as Figure 67, but Heated at 950° F. for 1 Minute

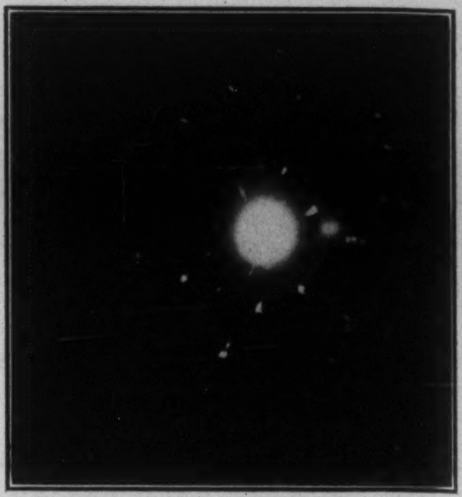

Figure 69—Same as Figure 67, but Annealed at 1100° F. for 1 Minute

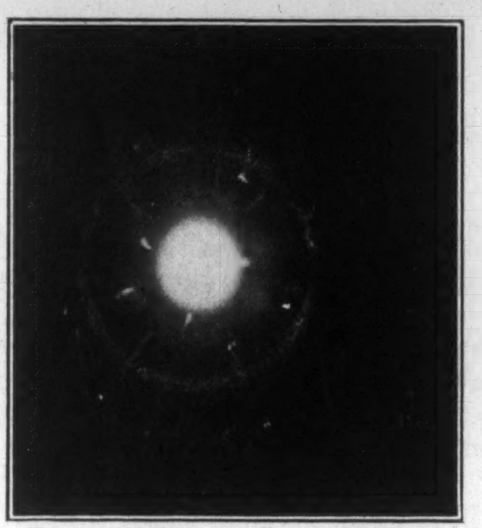

Figure 70—Same as Figure 67, but Annealed at 1300° F. for 1 Minute, Showing Appearance of New Orientation after Recrystallization

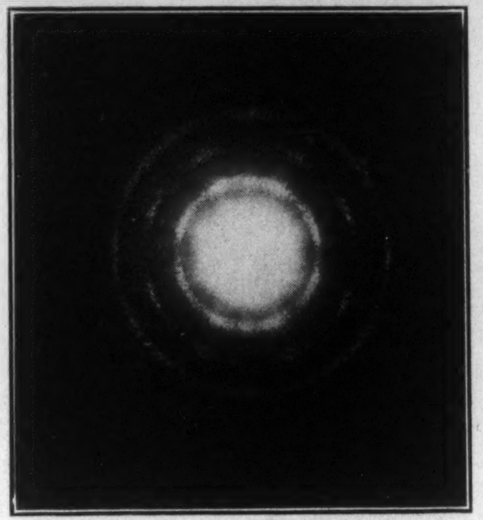

Figure 71—Same as Figure 67, but Annealed at 1600° F. for 1 Minute, Showing Recrystallization in New Preferred Orientation with [350] Direction Parallel to Direction of Rolling

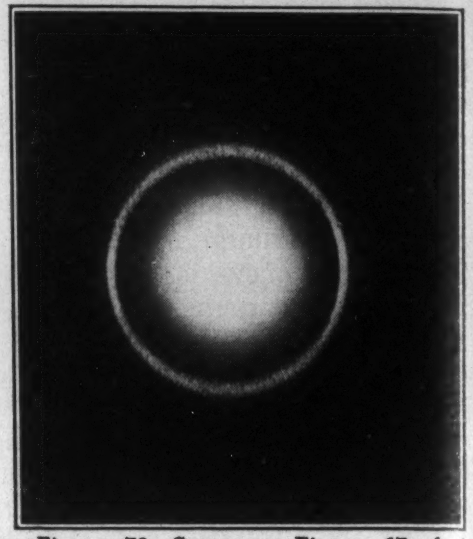

Figure 72—Same as Figure 67, but Heated above the Upper Critical Point; Only in This Way is the Fiber Structure Changed to Random

grains with the cube faces parallel to the rolling plane. Copper of ordinary purity, after complete reduction by cold rolling, tends to recrystallize with a chaotic arrangement of grains; but if a first reduction of 50 percent is made with hot rolls at 600° C., followed by cold rolling, the cubic recrystallization arrangement is so nearly perfect that the X-ray diffraction pattern indicates practically a single crystal (Figure 73). The further remarkable fact is that this structure persists clear to the melting point. Not only does copper differ from silver (dependent of course on the method of rolling), in an entirely different recrystallization orientation, but also in the fact that this never goes over to the random structure. It follows, therefore, that such a sheet has greatly different properties from one in which the grains are in disordered arrangement.

Element	Impurity Wt., %	Impurity Atomic, %	Recrystallization Temperature, ° C.
Electrolytic copper, unmolten	..	...	205
Electrolytic copper, melted	..	...	250
Tin	0.24	0.129	375
Silver	0.24	0.14	340
Lead	0.15	0.046	325
Manganese	0.23	0.267	320
Phosphorus	0.36	0.73	325
Cadmium	0.19	0.108	300
Antimony	0.06	0.032	280
Sulphur	0.21	0.42	275
Arsenic	0.14	0.119	250
Nickel	0.28	0.302	250
Gold	0.20	0.065	250
Silicon	0.06	0.13	245
Zinc	0.33	0.32	220
Bismuth	0.027	0.008	200
Iron	0.24	0.24	190
Aluminum	0.12	0.28	150
Cuprous oxide	18.0	8.33	150

A comparison of the tensile strength, elasticities and grain sizes of the two kinds of copper sheets is given in Figure 74. Both the strength and elasticity of the sheet with cube-face (oriented) grains are smaller than those of the random sheet. Czochralski has found that these properties are minimum in the direction of the cube edge, as is true here, while physical properties of the ordinary sheet are an average (higher) of all directions. The oriented sheet, however, is more resistant to corrosion than the random.

The effects of impurities as ascertained by Widmann from X-ray patterns are as shown in accompanying table.

f. The Recrystallization of Silver-Copper Alloy.—In light of the foregoing results with pure silver and copper, it is interesting to compare the X-ray results on sheets of an 80:20 silver-copper alloy.[16]

For a strip rolled down to 98 percent, the tensile strength is 90 kg./mm.^{2} as compared with 40 for silver and 50 for copper. After annealing at 800° the strength is only 30. The elongation of the alloy becomes noticeable only above 300° but approaches that of silver (20 percent) after treatment at 800°. While the softening and recrystallization lies in a range of only about 20°, the range in the alloy lies between 200 and 700° C. Mixed crystals, embedded in the eutectic and richer in copper, are brought out when the specimen is heated nearly to the melting point. Even heating for hours at 780° shows only a few of these crystals because the grains are smaller than 2μ; at 800° the grains are five times larger but show no preferred orientation. The first evidence of recrystallization in the X-ray photographs appears at 400°, when some diffuse lines become sharply resolved into doublets. Unless the specimen is heated for hours above 780° X-rays give the typical diagram of rolled silver.

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[16] Glocker and Widmann, *Z. Metallkunde*, **20**, 129 (1928).

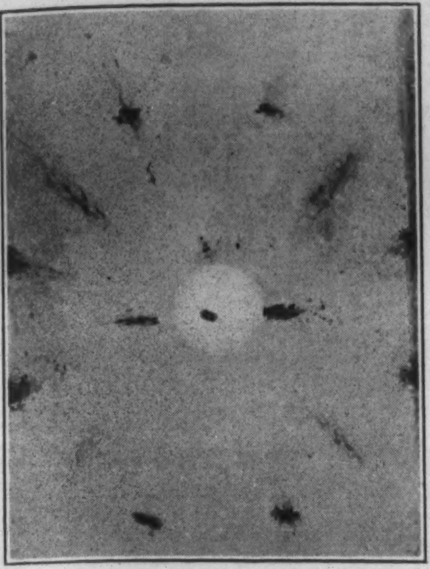

Figure 73—Recrystallization Structure of Copper Foil Reduced Partly by Hot Rolling, Showing Almost Perfect Orientation of All Copper Grains with Respect to Direction of Rolling and to the Surface of the Sheet

4. The Recrystallization of Wires. The drawing of metals into wires represents also a fibering of the grains but with a different mechanism which is somewhat simpler as will be explained in the next section. For all face-centered cubic metals (silver, copper, aluminum, gold, lead, etc.) a [111] direction, or cube body diagonal, is parallel to the wire axis with every possible orientation of the cubes (360°) around the diagonal; for body-centered cubic metals (α-iron, molybdenum, tungsten, etc.) a [110] or cube-face diagonal is parallel to this axis. In general there are no intermediate new orientations of grains during recrystallization by heat treatment. Instead the sharply localized intensity maxima in the diffraction patterns for the wires gradually become more indistinct with increasing temperature. The last traces of fibering are remarkably persistent and an entirely random arrangement is attained only after annealing near the melting point.

Sachs and Schiebold[17] have compared the X-ray diagrams and the tensile strength of a cold-drawn aluminum wire (1.18 mm.) after various annealing treatments. The treatments and tensile strengths are as follows:

	Kg./Mm.^{2}
Original	24.4
150°, 1/2 hour	18.7
200°, 1/2 hour	14.3
250° 350° } 1/2 hour 550°	11.0

The X-ray diagrams show a gradual increase in particle size with dots appearing on a continuous background of the diffraction rings at 250 and 300°; at 550° there appear large spots, far fewer in number but still lying on rings. At 150° the interference maxima broaden, indicating a departure of the oriented particles from perfect alignment, but even after annealing at 550° strong evidences of fiber structure remain.

Recrystallization of Pure Aluminum Wires

An exception to the general effect of annealing, however, is observed with very pure aluminum wire.[18] It has been found that on heating hard aluminum wire (0.35 or 0.8 mm. diameter, 99.95 percent pure) at 600° for 3 hours, recrystallization occurs with perfect undirectional orientation of the grains with a [111] direction parallel to the wire axis. This orientation is the same as in the original cold-drawn wire, so that aluminum differs from copper in this respect, and of course from aluminum of lesser purity. The texture of the wire seems very nearly unchanged by the treatment, but the tensile strength has decreased from 20.6 kg./mm.^{2} to 3.5, and the elongation has changed from 1 to 5 percent (single crystal wires 20 percent). Here it is clear that the grain orientation is not the only factor governing elastic properties.

For aluminum-silicon alloy wires, the strength decreases from 26.5 to 15.6 kg./mm.^{2} after heat treatment, the elongation increases from 2 to 17 percent, but the grain orientation and texture indicated by the X-ray pattern are unchanged.

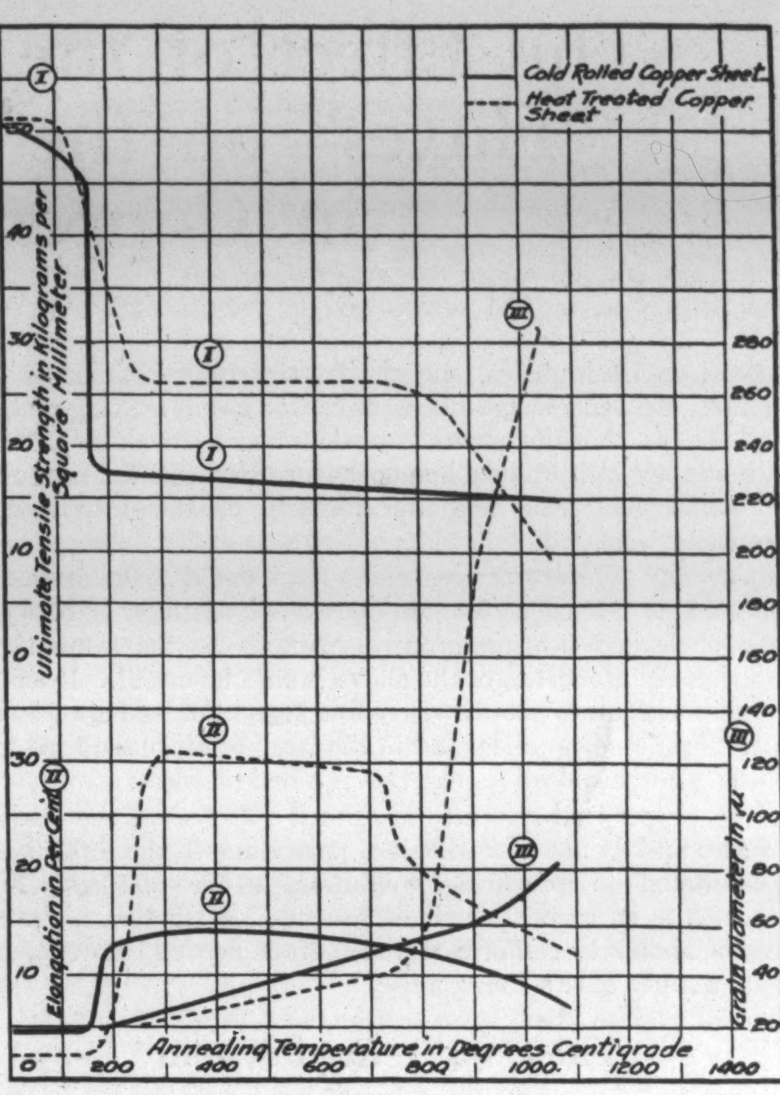

Figure 74—Tensile Strength, Elongation and Grain Size of Cold-Rolled Copper Sheet (Full Lines) and of a Sheet Reduced 50% by Hot-Rolling and 50% by Cold-Rolling (Dotted Lines) as Functions of Annealing Temperature. (Glocker and Widmann)

The single case of intermediate recrystallization preferred orientation is with deeply drawn copper wire annealed above 1000° C.[19]

The new orientation is with a [112] direction, instead of [111] parallel to the wire axis. This observation is further substantiated by Tammann and Meyer who counted in a cross section the following orientations of faces: (111) 27 percent, (101) 12 percent, (100) 61 percent; whereas theoretically for chaotic arrangement the proportions are respectively 38, 40 and 22 percent. Such a wire acts as a single crystal as compared with ordinary wires with random orientation. Following are the comparative data:

Treatment	Tensile Strength, Kg./Mm.^{2}	Elasticity, %
Original	49.3	1
300°	24.4	30
800°	23.9	23
1000° (3 hours) (oriented)	21.3	17

In general the X-ray study of wire annealing is not quite so satisfactory as that of rolled foils. Studies on crystalline wires of zinc and tin by Polanyi and his associates prove that often the change in mechanical properties and recrystallization evidence in X-ray patterns do not run parallel, since under certain conditions of original cold working and annealing these crystals may soften without evidence of recrystallization.

In the final Part V of this paper there will be considered the following topics:

9. The Analysis of the Mechanism of Fabrication of Metals and Alloys from X-ray Fiber Diffraction Patterns.

10. The Structure of Electrodeposited Metals.

11. Practical Applications of X-ray Methods to Problems of Metallurgical and Mining Industry (illustrated by numerous photographs).

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[17] *Z. Metallkunde*, **17**, 400 (1925).

[18] Schmid and Wassermann, *Z. tech. Physik*, **9**, 106 (1928).

[19] Schmid and Wassermann, *Z. Physik*, **40**, 451 (1926).

The Effect of the so-called Utah Shale "Fluxes" on the Dispersion of Lead in Copper-Lead Alloys

By G. L. Craig*

Various Utah shales, and similar materials from other localities, are being suggested as fluxes for use in melting metals and alloys. A claim generally made for such so-called "fluxes" is that they will produce homogeneous, disseminated mixtures of copper and lead, and are similarly beneficial to leaded bronzes.

Any flux, process or treatment that would make it easier to produce homogeneous non-segregated castings of copper-lead or leaded bearing bronzes, without at the same time injuring the properties of the alloys, would be useful. Bearing bronzes with up to about twenty-five percent of lead are widely used in railroad practice, and in the large castings required for railroad bearings lead segregation is a real problem.

The copper-lead mixtures are much softer than the leaded bronzes and do not find wide use, partly due to the difficulties encountered in preparing well-disseminated castings. For bearings to be used under light pressure, or where a high degree of ability to conform to the shaft is needed, the copper-lead mixtures offer some promise.

The Copper–Lead System

The equilibrium diagram of the copper–lead system has been investigated by Roberts-Austen,[1] Heycock and Neville,[2] Hiorns,[3] Friedrich and Leroux,[4] Giolitti-Marantonio,[5] and Waehlert.[6]

The exact solubility of copper in lead and of lead in copper is somewhat in question, but is certainly very small in the solid state. Hence the solid alloys consist of mixtures of practically pure lead in copper, or as the lead-copper eutectic contains so little copper (0.06%) it may, for all practical purposes, be considered pure lead.

The melting point of the alloys on the copper-rich end is lowered to about 955° C., as the lead is increased to 40 percent. In the range 40 percent to 64 percent lead, the melt is one homogeneous liquid at temperatures above 1025° C. When the temperature reaches 953° C., the melt separates into two conjugate liquids, one rich in copper and one rich in lead. The upper curve in Figure 1 was plotted from the recent investigation of Waehlert, while the balance of the curve was plotted from results of investigations made by Friedrich and Leroux. Plotting the data of Hiorns and Roberts-Austen gives a diagram differing but slightly from Figure 1.

As the melt cools, the two conjugate liquids change in composition until one contains about 40 percent lead and the other 84 percent lead. At 955° C., keeping the temperature constant, copper freezes from both liquids, as indicated by the flat portion of the curve, the lead remaining molten till about 325° C. has been reached.

The term flux is loosely used. As applied to additions made to a melt of copper and lead, a covering of glass or of borax whose object it is to prevent access of air and thus prevent formation of copper and lead oxides, and at the same time to dissolve copper oxides and lead oxide if formed, would be properly termed a flux. The usual object of a flux in metal melting is to eliminate some undesirable material such as oxides, by forming a fusible slag which dissolves the oxides, such fluxes being distinguished by fusibility and insolubility in the metal melt. Anything that tends to separate metals and their oxides, whether by chemical or mechanical action, may similarly be loosely termed a flux.

From the mechanism of solidification it is obvious that an effective method of obtaining an even distribution of lead is by stirring the molten metal as long as possible, so to speak, so that the temperature range in which the two liquid layers may separate may be as small as possible. If, after pouring, the melt is chilled it will freeze rapidly and hence less opportunity is given for the copper crystals to float. In any comparison

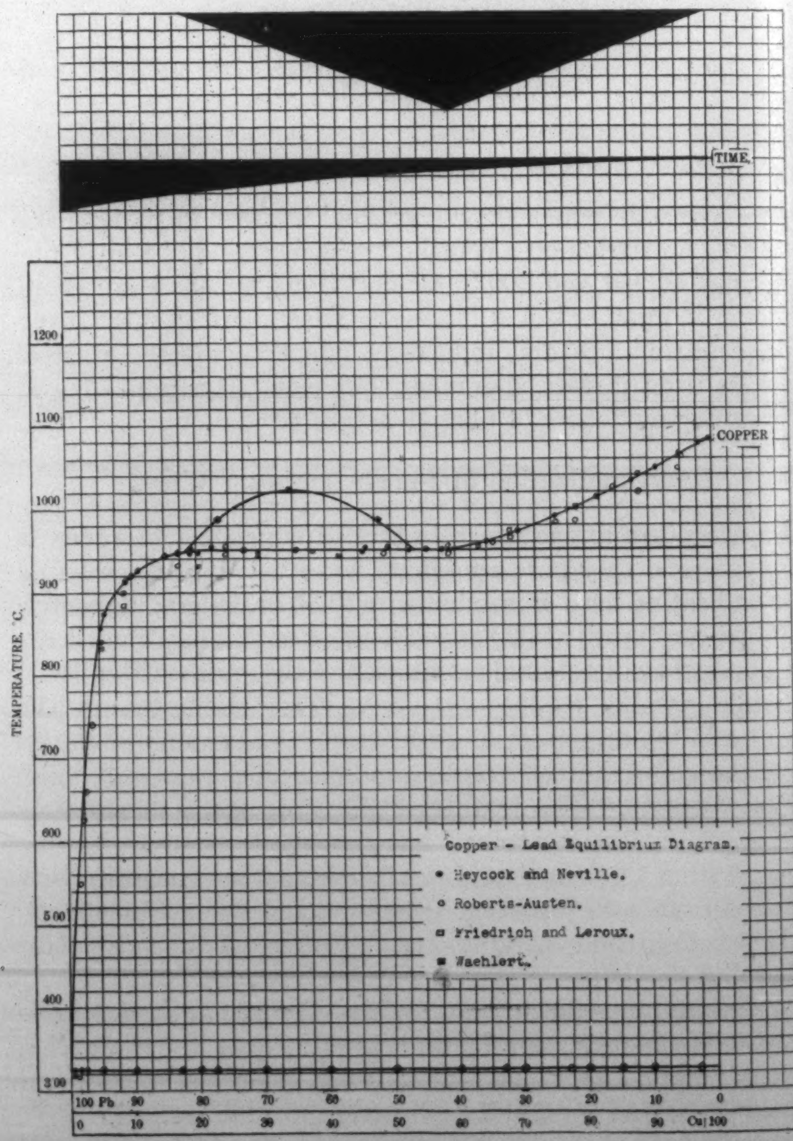

Figure 1

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* Fellow, Department of Mining and Metallurgical Research, University of Utah, 1928–29. This Department is conducted in cooperation with the Intermountain Station of the U. S. Bureau of Mines. A Thesis on this subject was submitted by Mr. Craig in partial fulfilment of the requirements for the degree of Master of Science. The work was directed by Dr. R. A. Bradford, Professor of Metallurgy, assisted by the Director of the Utah Engineering Experiment Station and other members of the Station staff.

[1] Roberts-Austen, *Eng.*, **63**, 225 (1897); *Proc. Inst. Mechanical Eng.*, **31**, (1897).

[2] Heycock, C. T., and Neville, F. H., *Proc. Roy. Soc.*, **60**, 160 (1896); *Phil. Trans. A.*, **XLII**, 189 (1897).

[3] Hiorns, A. H., *Jour. Soc. Chem. Ind.*, **25**, 616 (1906).

[4] Friedrich and Leroux, *Metallurgie*, **IV**, 293 (1907).

[5] Giolitti, F. and Marantonio, M., *Gazz. chim. ital.*, **40**, 1 (1910); Guertler, "Metallographie," **1**, I, page 597.

[6] Waehlert, H., *Metall und Erz*, **X**, 575, 976 (1913).

of copper-lead alloys, melted with and without a flux, it is therefore necessary to control the stirring, the pouring temperature and the rate of cooling in order to obtain a proper basis of comparison. Accordingly, in making the tests discussed in this paper these factors were kept as constant as possible so as to determine if the claims made for the so-called Utah shale were justified.

The Shales

The shales alleged to have the properties described above exist in a rather widespread area of Emery and Grand Counties, Utah. Their occurrence is abundant and the existence of many outcrops makes the shales easily available. They vary in color from a dark reddish brown to black and between the bedding planes is generally found a yellow powdery deposit—probably limonite. They are typical carbonaceous shales and have a cleavage along the bedding planes.

The following are the analyses reported by the Reno Station of the United States Bureau of Mines of the two samples of the shales used in this investigation.

	Shale A[a]	Shale B[b]
SiO_2	45.71	63.02
Al_2O_3	14.85	15.72
Fe_2O_3	5.50	3.45
TiO_2	0.58	0.91
CaO	0.81	0.34
MgO	0.45	1.21
K_2O	1.05	2.00
Na_2O	0.24	1.09
Loss minus 105° C.[c]	5.53	3.44
Loss plus 105° C.[d]	25.23	7.69
Vanadium	Nil.	Nil.
Molybdenum	Nil.	Nil.
Tungsten	Nil.	Nil.
	99.95	98.87

[a] Shale A from Northern Emery County.

[b] Shale B from Southeastern Emery County.

[c] Chiefly moisture.

[d] Represents water of composition, carbon dioxide and carbonaceous material. Carbon was present but not separately determined.

Experimental Procedure

Small plumbago crucibles of about a kilogram capacity were used in melting the charges in a gas-fired crucible furnace. Pure copper was used, cut in small pieces. Charcoal was used for a covering. The charge was melted and brought to a temperature of 1120° C. (1105–1140). Pure lead was then added, and the temperature allowed to drop to 1000° C. (990–1010). An optical pyrometer was used in measuring temperatures. The crucible was covered during all melting operations with a plumbago cover. The melt was vigorously stirred with an iron rod while cooling and the crucible was moved so as to swirl the melt up to the moment of casting.

Preliminary tests showed that for the size castings being prepared (about 400 grams), with a lead content of from 30–50 percent, an increase in pouring temperature above 1000° C. increased the lead segregation till at 1200° C. settling became a factor.

Below 990° C., the metal froze in the crucible before the mold could be filled. Above 1010° C., the segregation was quite noticeable.

Casting

Chill, green sand and dry sand molds were used in preparing the castings. The chill mold was constructed from a thick-walled cast-iron pipe with inside dimensions of 3 inches in height and 1 inch in diameter. The resulting casting was a cylinder 1 inch in diameter by 3 inches long, cast vertically. The weight of the mold was approximately 1000 grams, that of the casting about 400 grams.

The sand molds were made in flasks 12″ × 12″ × 8″ high, the pattern being a 1-inch rod 3 inches long, the casting being made vertically. The castings weighed approximately the same as those produced in chill molds, i. e., 400 grams.

The dry sand molds were oven dried to drive off moisture before use, but were at room temperature when used. In the early experimental work the castings were poured horizontally and gated, i. e., the longest axis was horizontal, but this practice was discontinued in preference to casting vertically, where such relatively small castings were being prepared.

The castings were allowed to remain in the molds for varying times (see curves) in order to determine the effect of time of cooling on average particle size. In the chill mold from $^1/_2$ to 15 minutes was allowed. Those cooled $^1/_2$ to $1^1/_2$ minutes, inclusive, were water quenched; those cooled from 2 to 15 minutes were removed from the mold and air quenched; when the cooling time was longer than 15 minutes the gates were covered with dry sand and at the end of the specified period the castings were shaken out. In the sand molds, those cooled for $^1/_2$ to 7 minutes were water quenched, and the others were shaken out of the molds after 8 to 25 minutes.

Use of the Shale. When the shales were used, the procedure was exactly as above, save for the addition of the shale. The shales were ground to pass 100 mesh and were added in the preliminary tests in varying amounts and in different manners. When shale was used in the charge to the extent of 10% of the weight of the metal, particles of the shale were, as a rule, entrapped in the castings and appeared in the castings as inclusions of blue slag.

Heats were made with (1) all of the shale added with the copper, (2) all with the lead, (3) after addition of the lead, when the whole charge was completely liquefied, (4) half with the copper at the start and half with the lead. These methods were also tried on charges of varying lead content, and with both Shale A and Shale B.

On comparing the results of these preliminary tests with and without shale, no difference in segregation of lead could be noticed in any case whether the shale was used or not. Little difference was observed between the action of Shale A and B in the investigation, as both gave practically the same results in duplicate runs. Shale A was used exclusively in the preparation of the castings for particle count, as shown in the accompanying charts.

For quantitative study, a mixture of 60 percent copper and 40 percent lead was chosen. The mixtures were heated to

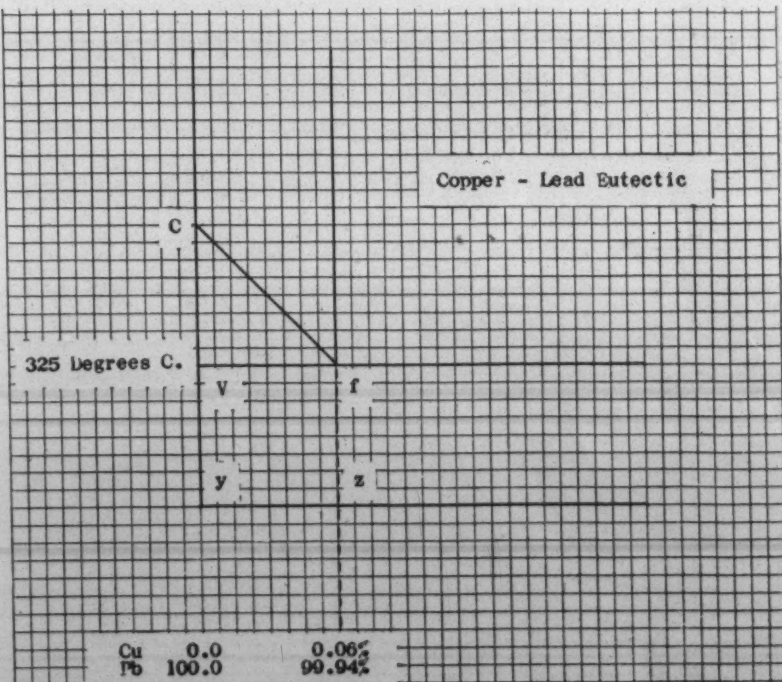


Figure 2

1120° C. and poured at about 1000° C. In each case melts were made with and without the addition of the shale flux. A series of castings was poured in chill, green and dry sand molds. When the shale flux was used, a series of castings was made in which the amount of flux used was 10% of the total weight of the metal charged.

Examination of Castings. Three specimens were taken from each casting for microscopic examination, one at the top, one at the bottom and one at the center. The specimens taken from the top and bottom were roughly polished to determine the relative amounts of lead. The center specimen was carefully prepared, for determining particle size, as representative of the casting as a whole.

The pouring temperature for these small castings was kept at 1000° C. No gross segregation of lead occurred at the bottom of the cast except when the melt was overheated. While more lead, in general, was found at the bottom of the casting than at the top, it appeared that the distribution of lead at the center of these small castings gave a fair measure of the degree of uniformity of the dispersion of lead throughout the whole casting.

Figures 3, 4 and 5 show the distribution of lead at the center of the casting.

The metallographic specimens were sawed out and smoothed by hand by using Numbers 0, 00, 000 and 0000 Huber emery paper moistened with kerosene. Final polishing was performed on a slowly revolving felt-covered wheel with a suspension of alundum in water. Final polishing was carried out on a clean pad dampened with distilled water, followed by a short time polish on a dry wheel. This method of polishing proved to be quite satisfactory for this type of alloy.

The specimen was then examined without etching, and the image at 150 diameters magnification projected onto the ground glass of a metallurgical microscope.

The ground glass was ruled so that the dimensions of the lead particles were measured in hundredths of millimeters, and later reduced to microns. A particle count was made across the full width of the specimen, both horizontally and vertically, thus giving a comparatively accurate estimate of the average size and number of the particles.

The lead particles were present in two types, one consisting of small, quite uniformly distributed particles, and the other of less uniformly distributed larger patches. An arbitrary distinction was made by which particles over 100 microns diameter were called "segregations."

In recording the data the average particle size of the small particles is given, while for the segregations not only the average size but also the number observed in a representative field are recorded.

As shown in Figures 3, 4 and 5 the particle sizes of the lead in a 60 percent copper, 40 percent lead mixture were about as follows.

Chill mold	8–12 microns
Dry sand mold	12–85 microns
Green sand mold	20–80 microns

The particle size increased as the cooling time increased.
The segregations were as follows:

	Number of Segregations across the Specimen	Diameter of Segregations, Microns
Chill mold	1–8	100–155
Dry sand mold	9–80	105–250
Green sand mold	11–85	110–240

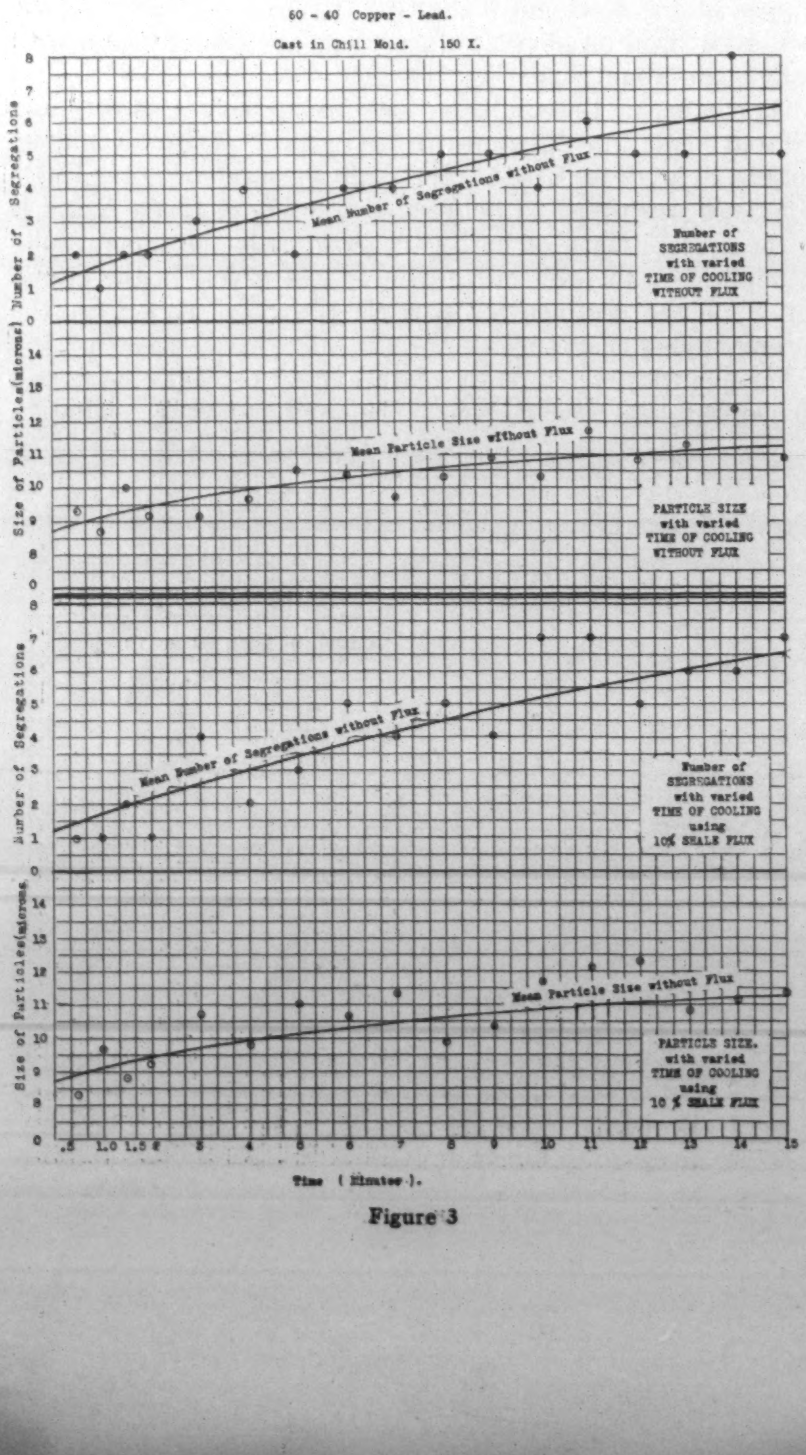

60 - 40 Copper - Lead.
Cast in Chill Mold. 150 X.

Figure 3

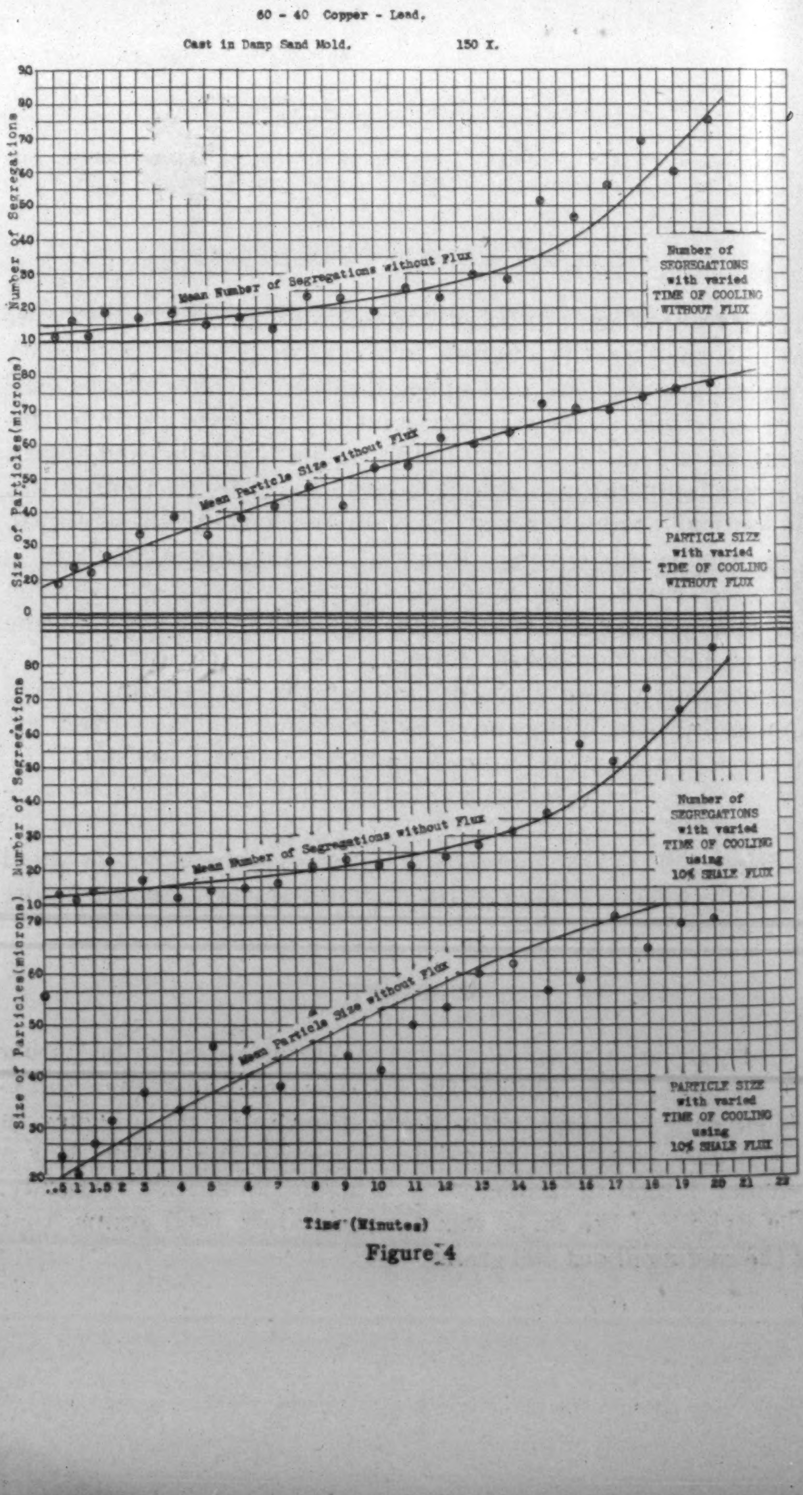

60 - 40 Copper - Lead.
Cast in Damp Sand Mold. 150 X.

Figure 4

The method of graphically presenting the data in Figures 3, 4 and 5 is as follows. The relation between particle size and time *without flux* is determined as shown by the top curves. These curves are then transferred to the two lower plots showing the points obtained *with flux* so that the agreement of the results with and without the use of flux can be seen.

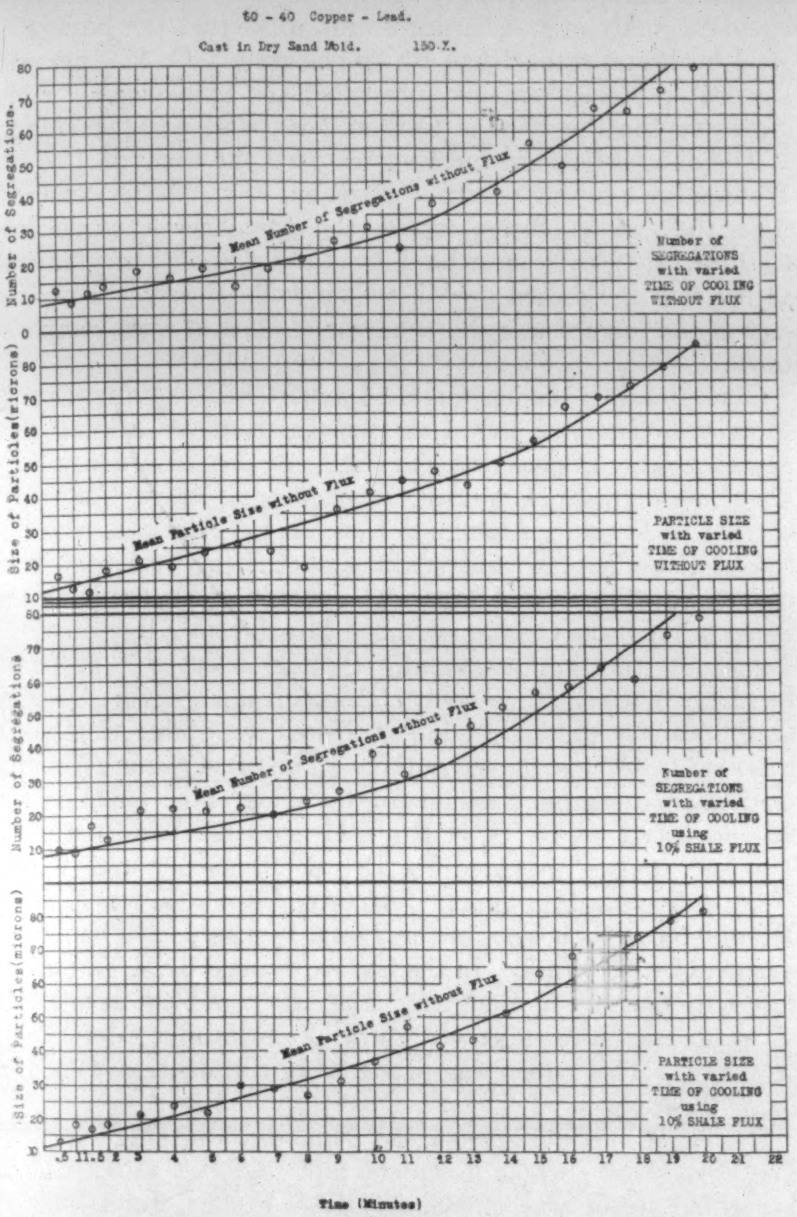


Figure 5

An inspection of the graphs shows in all cases a rather close agreement between the transferred curve and the determined points which indicates that no increased dispersion was obtained by the use of the shale flux.

The experimental results indicate that under the conditions investigated the shales used are without effect upon the distribution of the lead particles in copper-lead mixtures.

No beneficial effect of the shale was noted in any respect. The shales appear to have no "fluxing" action of any sort. The only effect noted was a detrimental one, namely, the tendency of the casting to contain included particles of shale.

Acknowledgment

The writer wishes to thank Dr. D. A. Lyon and Mr. S. R. Zimmerly of the United States Bureau of Mines for their kindness in carefully going over the manuscript, and to Dr. R. H. Bradford and Mr. W. E. Keck, of the Department of Mining and Metallurgical Research of the University of Utah, for their helpful suggestions relative to the preparation of the alloys.

American Manganese Producers Association Convention

The Second Annual Convention of the American Manganese Producers Association was held at the Mayflower Hotel, Washington, D. C., on September 9–10.

As was natural in a year when tariff revision was under consideration and at a meeting of an industry which possibly owes its existence to a protective tariff, this question colored most of the addresses delivered. The consensus of opinion seemed to be that a sound domestic industry was only possible under a tariff which would permit the sale of 65-cent manganese.

At two interesting sessions dealing with recent developments in manganese treatment, Mr. Wilson Bradley, president of the Bradley-Fitch Company, discussed his process for the leaching of low-grade manganese ores. Mr. F. D. DeVaney told of the work of the U. S. Bureau of Mines at its Mississippi Valley Experiment Station, Rolla, Missouri, on the flotation of carbonate and oxide manganese ores. Mr. DeVaney accompanied his paper with a very convincing demonstration of the process. This method has shown the feasibility of cheaply floating low-grade carbonate ores, separating rhodochrosite from rhodonite, silica, etc., and in similarly treating those oxide ores which have heretofore been regarded as difficult or impossible to handle such as ores which slime too greatly to allow tabling or which require extremely fine grinding to release the mineral particles. Mr. Adrian Nagelvoart, of the Delaware Chemical Engineering Company, described the separation of minerals by means of the heavy liquid, acetylene tetrabromide. His company has recently developed an apparatus for the use of this material which is claimed to be very economical in operation. Professor A. T. Sweet, of the Michigan College of Mines, outlined the fundamental principles to be sought in any successful process for the leaching of low-grade ores. It is understood that Professor Sweet has developed several processes which meet these requirements but about which he was extremely reticent.

The state roll call brought responses from the various operators on the conditions of the industry in each district. The most significant developments during the past year have been the proving of two large ore bodies, each of about 50 million tons, averaging from 10 to 20% manganese, one in Arizona by the Chapin Exploration Company and the other in South Dakota by the General Manganese Corporation.

An advisory board was recently appointed for the School of Mines and Metallurgy at Pennsylvania State College. The board is to assist in helping the college better serve the iron and steel industries of the state. The members are: F. D. Andrews, general superintendent, Harrisburg Pipe and Pipe Bending Co., Harrisburg; L. R. Custer, general manager, Cambria works, Bethlehem Steel Co., Johnstown; A. N. Diehl, Vice-President, Carnegie Steel Co., Pittsburgh; Dr. H. L. Frevert, Vice-President in charge of operations, The Midvale Co., Nicetown, Philadelphia; T. M. Girdler, President, Jones and Laughlin Steel Corp., Pittsburgh; C. W. Heppenstall, President, Heppenstall Forge and Knife Co., Pittsburgh; Dr. C. H. Herty, Jr., supervising metallurgist, Bureau of Mines Experiment Station, Pittsburgh; Roy C. McKenna, President, Vanadium Alloys Steel Co., Latrobe; E. J. Poole, Vice-President and general manager, Carpenter Steel Co., Reading; O. C. Skinner, works manager, Standard Steel Works Co., Burnham; H. C. Thomas, Vice-President, the Alan Wood Co., Philadelphia; F. M. Waring, engineer of tests, Pennsylvania Railroad, Altoona; Charles A. Waters, secretary of labor and industry, Harrisburg; and Dr. H. W. Gillett, director of the Battelle Memorial Institute, Columbus, Ohio.

National Metal Congress

The National Metal Congress, held in Cleveland during the week of September 9th, was by far one of the largest ever held. Four societies, American Society for Steel Treating, Iron & Steel Division of the A. S. M. E., Institute of Metals Division and Iron and Steel Division of the A. I. M. E. and the American Welding Society, cooperated. The technical sessions, which were held both morning and afternoon, covered every phase of the production, selection, fabrication, inspection and testing, welding and application of metals and alloys.

American Society for Steel Treating

The first session was opened at 10:00 A.M. Monday by W. H. White, chairman of the Cleveland chapter, who introduced Dr. Zay Jeffries, president of the Society. Dr. Jeffries extended a brief welcome to the visitors and then turned the meeting over to R. M. Bird, chairman. At this session papers were read by G. M. Eaton, Molybdenum Corporation of America, on "Dilatation of Steel during Quenching;" H. B. Knowlton, International Harvester Company, on "The Economical Reuse of Solid Carburizing Materials;" H. W. McQuaid and O. W. McMullan, Timken-Detroit Axle Company, "The Selection of Case Hardened Steels for Highly Stressed Gears." This paper was abstracted by Mr. McMullan.

At the afternoon session at which Prof. Bradley Stoughton presided, Dr. Anson Hayes, American Rolling Mill Company, read a paper entitled "Conditions Necessary for Blistering of Metal during Processing;" H. G. Keshian, Chase Metal Works, "Dendritic Steel;" W. J. Merten, Westinghouse Electric & Manufacturing Company, "Improving of Refractory Lining of Heat Treating Furnaces for High Temperature Annealing of Steel Castings" and Prof. W. E. Jominy, University of Michigan, "Overheating of Steel for Forging."

The Tuesday morning session found Radclyffe Furness, Midvale Company, officiating as chairman. He introduced as the first speaker George Batty, Research Director, Steel Castings Development Bureau, who described the methods applied in melting and finishing a heat of electric steel for casting. The next speaker, G. A. Dornin, Gathmann Engineering Company, whose paper, "Slags Produced in Steel Making, Their Effects on the Product and on the Process Itself," concerned itself with flaws and the lack of reliable uniformity that must follow in steel made by processes which attempt to finish and refine under iron oxide bearing slags. H. P. Rassbach, Midvale Company, Nicetown, Philadelphia, read a paper on the electric melting practice for carbon tool steel, chrome-vanadium steel and high-speed steel. The final paper of the morning session was by Lawford H. Fry, Standard Steel Works, entitled "Locomotive Forgings." Mr. Fry compared the various melting processes, considering the importance of ingot structure, types of steel and forge-practice.

H. J. Stagg occupied the chair at the Tuesday afternoon session and the first paper, "Methods of Tests for Determining the Machinability of Metals in General, with Results," by O. W. Boston, University of Michigan, described a series of tests made on 18 ferrous metals and 21 non-ferrous metals, correlating the hardness with machining qualities. The second paper, "On the Distribution of Hardness Produced by Cold Working," by W. P. Sykes, General Electric Company, and A. C. Ellsworth, Thompson Products Company, was read by Mr. Sykes. "Inherent Hardenability Characteristics of Tool Steel" was the title of a paper by B. F. Shepherd, Ingersoll-Rand Company. He found no relation between chemical analysis and hardness and advocated the buying of steel by brand rather than by specification. G. V. Luerssen, Carpenter Steel Company, presented the final paper, "Some Notes on the Behavior of Carbon Tool Steel on Quenching."

The annual business meeting occupied the early part of the Wednesday morning session. President Zay Jefferies presided. After the various officers' reports the meeting was turned over to Prof. H. Boylston, who introduced Dr. Albert Sauveur as the fourth Edward de Mille Campbell lecturer. The subject of the lecture was the behavior of steel at high temperatures.

The afternoon session was held jointly with the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers. The first speaker, introduced by the Chairman, P. D. Merica, International Nickel Company, was R. L. Templin, Aluminum Company of America, who discussed the effects of cold working on the physical properties of metals. The second paper, "A Method of Determining the Orientation of the Crystal in Rolled Metal from X-ray Patterns Taken by the Monochromatic Pinhole Method," prepared by Dr. Wheeler P. Davey, Pennsylvania State College, C. C. Nitchie and M. L. Fuller, New Jersey Zinc Company, was read by the last named author. The preparation of microsections of tungsten carbide for metallographic examination was described by Dr. S. L. Hoyt, General Electric Company. The next paper, prepared by Dr. R. S. Archer and W. L. Fink, both of the Aluminum Company of America, was entitled "Radiography as a Tool in the Metal Industry." This paper was read by Mr. Fink. In the last paper read by H. B. Smith, International Silver Company, the effect of heat treatment on properties and microstructure of Britannia Metal was discussed. This paper was prepared in conjunction with Dr. Birger Egeberg.

Dr. H. W. Gillett opened the Thursday morning meeting. The first paper, which discussed hot aqueous solutions for quenching steels, was offered by H. J. French, International Nickel Company, and T. E. Hamill, Bureau of Standards. The second paper, "A Study of the Iron-Chromium-Carbon Constitutional Diagram," prepared by V. M. Krivobok, Carnegie Institute of Technology, and M. A. Grossman, Central Alloy Steel Company, was abstracted by Dr. Krivobok. The paper of E. A. Sperry, "Non-Destructive Testing," was abstracted by Mr. Drake of the Sperry Development Company, Inc., in the absence of Mr. Sperry. The paper aroused considerable discussion. The final paper of the session was by H. H. Lester, Watertown Arsenal, and was concerned with the brittle range of iron containing 18% chromium and 8% nickel.

The Thursday afternoon session, at which Dr. O. E. Harder was chairman, two papers were presented on cast iron: "Graphitization of Pre-Quenched White Cast Iron," by H. A. Schwartz, H. H. Johnson and C. H. Junge, National Malleable and Steel Castings Company; "High Strength Cast Iron," by E. J. Lowry, consulting engineer. The other papers at this session were: "Austenite and Its Deposition," by Dr. Albert Sauveur, Harvard University; "Crystal Structure of an Iron Phosphide," by James B. Friauf, Carnegie Institute of Technology.

One of the most interesting sessions was the symposium on nitriding. The morning and afternoon meetings on Friday were devoted to this subject with Prof. G. B. Waterhouse, Massachusetts Institute of Technology, as chairman. The following papers were read: "The White Layer in Gun Tubes," by H. H. Lester, Watertown Arsenal; "Observations upon the Iron–Nitrogen System," by Samuel Epstein, Illinois Steel Company; "Study of the Nitriding Process,"by V. O. Homerberg and J. P. Walsted, Massachusetts Institute of Technology; "Researches on Nitriding Steels," by Dr. O. E. Harder, University of Minnesota; "Investigations in Nitriding," by Robert Sergeson, Central Alloy Steel Corporation; "Short Time Nitriding of Steels in Molten Cyanides," by A. B. Kinzel and J. J. Eagan, Union Carbide and Carbon Research Laboratories; "A Few Practical Fundamentals of the Nitriding Process," by H. W. McQuaid and W. J. Ketcham, Timken-Detroit Axle Company; and "The Use of Nitrided Steel in High Temperature-High Pressure Steam Service," by V. T. Malcolm, Chapman Valve Manufacturing Company. This collection of papers constitutes a complete reference on this subject and should prove very useful.

American Welding Society

The Ninth Annual Fall Meeting of the American Welding Society opened Tuesday morning. A. E. Gaynor officiated as chairman of the first technical session. The first paper by Henry G. Reist, General Electric Company, was devoted to the effect on design of the use of welding in the manufacture of electric machinery. He briefly traced the history of the use of structural steel in machinery. A lively discussion ensued. The next paper, devoted to the experiences of the author on cutting and welding, "Cutting and Welding Steel Parts to Replace Castings," was presented by W. F. Buchanan, Bessemer Gas Engine Company.

The afternoon session with Dr. H. L. Whittemore, U. S. Bureau of Standards, presiding offered two papers: "Welding of Copper and Copper Alloys," by I. T. Hook, American Brass Company; and "How to Test Welds," by F. G. Tatnall, Southwark Foundry and Machine Company.

The conference of research workers on fundamentals of welding met with the Wednesday morning session of the American Welding Society. In his introductory address, H. M. Hobart, chairman, stated that the art of welding is progressing rapidly. He praised the Society for its cooperative efforts in promoting research. Considerable data on fatigue tests of different types of welds were given by Prof. J. H. Thornton, Washington State College; Prof. G. Doan, Lehigh University, discussed work with pure iron welding wire. W. Spraagen, American Bureau of Welding, described German motion pictures of welds, which show what happens when metal is joined by welding. A study of stresses in welded rail joints was presented by Prof. Thomas R. Lawson, Rensselaer Polytechnic Institute.

At the afternoon session with J. J. Crowe, Air Reduction Sales Company, presiding, P. Alexander, General Electric Company, presented a "Study of Nitride Needles" which is a preliminary report of tests carried out by the author.

The second paper, "Chemical Reactions of the Carbon Arc," by G. E. Doan and E. Ekholm, Lehigh University, was read by Prof. Doan. The paper referred to many experiments which have been carried out using varying lengths of arc. The next paper by Dr. H. W. Boylston, Case School of Applied Science, and another by M. Yatsevitch, Watertown Arsenal, covered the metallographic study of welds.

Methods of non-destructive testing of welds applicable to plate, pressure vessels, pipe joints and structural steel joints were discussed in the first paper of the Thursday morning session by C. O. Burgess, A. B. Kinzel and A. R. Lytle, Union Carbide and Carbon Research Laboratories. The paper was presented by Mr. Kinzel and describes a method by which the presence of spots in the weld that are different in character from a satisfactory joint are first detected by means of a stethoscope and then X-ray photographs are made of these spots. Welding studies at Watertown Arsenal were described in the second paper by Major J. B. Rose, U. S. A. Ordnance Department. In the final paper, "Stress Strain Characteristic of Welded Joints," Prof. J. H. Smith outlined the stress-strain characteristics of welded joints.

The opening paper of the Thursday afternoon session, a joint session with the American Society of Mechanical Engineers, "Non-destructive Testing of Welds," by E. A. Sperry, was presented by H. C. Drake, Sperry Development Company. The equipment for making the inspection was described. W. L. Warner, General Electric Company, in a paper entitled "Automatic Arc Welding of Thin Sheets" pointed out that in order to accomplish fusion a certain amount of time is required depending on the nature of the material and effective heating power of the welding flame. The final paper at this session on "Foreign Practise in Welding Boiler Tubes and Drums" by G. A. Orrock was read by P. W. Swain.

Three papers were read at the Friday morning meeting with J. C. Lincoln, Lincoln Engineering Company, presiding: "Oxyacetylene Welding of Pipe Lines in the Field," W. R. Ost, Air Reduction Sales Co.; "Electric Welding of Field Joints of Oil and Gas Pipe Lines," H. C. Price, Welding Engineering Company; "Welding of Tubing and Pipes for Locomotives and Boilers," H. A. Woofter, Swift Electric Welder Company.—H. W. GILLETT.

Institute of Metals Division of American Institute of Mining and Metallurgical Engineers

The first session of the fall meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers was held in Cleveland, Ohio, on Tuesday, September 10th. This meeting was in conjunction with others composing the National Metal Congress sponsored by the American Society for Steel Treating.

Under the leadership of Prof. T. A. Wright as Chairman, four papers were presented comprising a symposium on the Utilization of Secondary Non-ferrous Metals and Alloys. An additional paper by R. W. Drier and C. T. Eddy on "Correlation of the Ultimate Structure of Hard-drawn Copper Wire with the Electrical Conductivity," was also made a part of the program. The subject had been investigated by the authors by X-ray methods and provided a lively discussion by representatives of wire mills.

A description of the "Manufacture of Wire Bars from Secondary Copper" by W. A. Scheuch and J. W. Scott brought to light the fact that while 490,000 tons of copper are obtained from secondary sources, the operations of the Hawthorne plant of the Western Electric Company are the only ones in which secondary copper has been used successfully. The authors described in some detail the underlying requirements for the satisfactory production of high conductivity wire bar from scrap materials.

In a paper by F. N. Flynn on "Reclaiming Non-ferrous Scrap Metals at Manufacturing Plants," classifications of scrap and notes on various processes were presented.

The "Utilization of Secondary Metals in the Red Brass Foundry" by H. M. St. John touched on a matter of great interest to the non-ferrous foundry interests. In Prof. St. John's paper the point was made that satisfactory casting could be produced from secondary alloys. He described methods of refining red brass in the electric furnace for the production of a melting base for the brass foundry.

The white metals were not forgotten by the committee, in that a paper by P. J. Potter on the "Recovery of Waste from

Tin-base Babbitting Operations" had been included in the symposium. The classification of materials was discussed by the author as well as methods of handling and disposal of the various products.

The session was well attended and the papers were subjected to a volume of discussion. The interest in the secondary metals was emphasized by the statement of the Chairman that their value for the year 1928 was $277,000,000 and their importance in national defense was stressed by a representative of the War Department.

The Thursday morning session of the Institute of Metals was marked by a presentation of papers in which a careful study of the constitutional diagrams of several alloys systems was made. In addition to the consideration given to physical metallurgy, several papers on manufacturing processes of nonferrous materials excited much discussion.

"The Metallography of Commercial Thorium," as covered in a paper by Edmund S. Davenport, provided a subject of great interest to those engaged in the manufacture of incandescent lamp filaments. The author presented very complete data covering tensile strength, ductility, annealing temperatures and a number of microstructures, particularly bearing on the oxygen content of thorium produced by a modified calcium-calcium chloride process.

W. E. Remners reported a study of a number of "The Causes of Cuppy Wire." The paper gave a micrographical study of tensile tests, X-ray examinations. The effect of die angle design was included as well as an interesting pantograph method of determining the die contours. The chemical causes of such defective wire was investigated from the standpoint of oxygen content. The subject was discussed at considerable length by W. A. Scheuch also of the Western Electric Co. from the standpoint of practical manufacture as contrasted with the theoretical study of the author.

E. A. Anderson presented a study of the "Effect of Alloying on the Permissible Fibre Stress in Corrugated Zinc Roofing." A compilation of the physical properties of alloyed zinc sheet which was of sufficient strength to enable it to meet the loading requirements in roof purlin spacing, appeared in the paper. This contribution represented a continuation of a previous investigation on this subject by the same author. The matter of corrosion of the alloyed sheet was brought up in the discussion.

"The System Cadmium–Mercury" received a very scholarly treatment in a paper presented by R. F. Mehl and C. S. Barrett. The crystal structure of mercury at −40° C. was determined and also the crystal structure of the cadmium-mercury alloy. Heating and cooling curves of the mercury rich alloy were illustrated, particularly at the lower temperatures. The constitutional diagram was discussed at considerable length and a new transition point reported.

Another paper on the study of constitutional alloys was presented by G. L. Hiers and G. P. de Forrest—"The Eutectic Composition of Copper & Tin." In this work they determined that the copper-tin eutectic contained 0.94 of copper. Their work confirmed that of other investigators of this subject. The copper and tin alloy received further attention by R. F. Mehl and C. S. Barrett in a "Note on Crystal Structure of the Alpha Copper-Tin Alloys." By X-ray diffraction methods and density determinations, the crystal structure of this alloy was studied. The solid solution was found to be simple substitutional in type.

In recent years the question has been raised of the use of deoxidizing copper for applications exposed to reduced gas. Earle E. Schumacher, W. C. Ellis and J. F. Eckel have compiled a paper on "Deoxidation of Copper with Calcium and the Properties of Some Copper-Calcium Alloys." The authors prepared alloys of this nature and presented the results of a study of the physical properties and electrical conductivity. The alloy was found to be satisfactory for commercial use. In the discussion, question was raised as to the conductivity of copper in the cast and rolled conditions.

S. L. Hoyt presided as chairman, and guided the discussion along the lines of interest to those in attendance. This session closed the very satisfactory program of the fall meeting of the Institute.—W. F. GRAHAM.

Iron and Steel Division of American Institute of Mining and Metallurgical Engineers

The activities of this division of the American Institute of Mining and Metallurgical Engineers commenced Tuesday afternoon with a technical session. Prof. George B. Waterhouse, Massachusetts Institute of Technology, chairman of the division, headed the meeting. The paper presented by B. A. Rogers, Western Electric Company, "The Change in Microstructure of Iron at the A_3 Transformation Point," gave a description of the apparatus used in performing the experiments. The next paper, "A New Development in Wrought Iron Manufacture," by Dr. James Aston, Carnegie Institute of Technology, aroused considerable discussion. The process, as Dr. Aston described, is an application of fundamental chemical facts to a major metallurgical problem. Moving pictures of the process as used at the A. M. Byers Company, Warren, Ohio, were shown. The concluding paper of this session was by T. L. Joseph, U. S. Bureau of Mines, in which he discussed blast furnace filling and size aggregation.

The Wednesday morning session was opened under the leadership of C. B. Murray as chairman. The following papers were presented: "Fluorspar and Its Uses," by Earl Brokenshire, Oglebay, Norton and Company; "Foreign Iron Ones," by Charles Hart, Delaware River Steel Company; "Iron Ore Sinter," by G. M. Schwartz, University of Minnesota; and "The Bradley Process for the Beneficiation of Manganiferous Ores," by Carl Zapffe, Northern Pacific Railroad.

Two papers were presented at the Thursday afternoon session at which Prof. Waterhouse again officiated as chairman. Both papers discussed open hearth slags. Dr. C. J. Herty, Jr., U. S. Bureau of Mines, read a paper entitled "Diffusion of Iron Oxide from Slag to Metal in the Open Hearth Process." The title of the other paper was "Experimental Data on the Equilibrium of the System Iron Oxide–Carbon in Molten Iron," by A. B. Kinzel and J. J. Egan, Union Carbide and Carbon Research Laboratories.

Iron and Steel Division of American Society of Mechanical Engineers

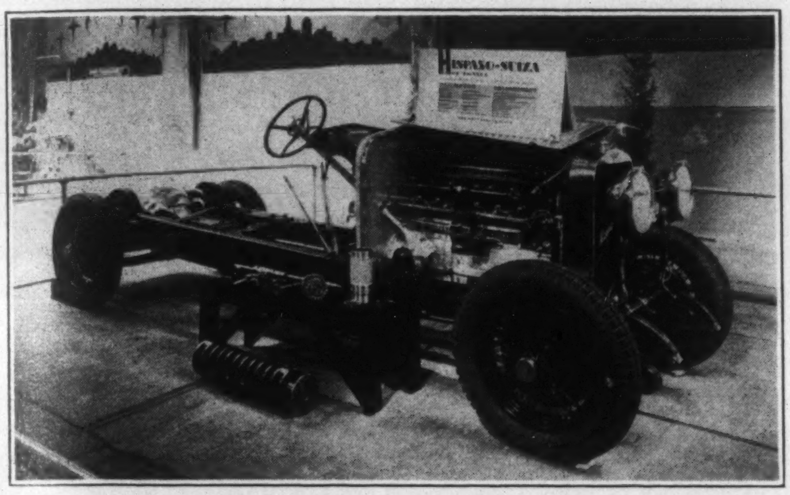
The sessions of the American Society of Mechanical Engineers opened on Wednesday afternoon. The meeting on Thursday afternoon was a joint session with the American Welding Society. The concluding sessions were held on Friday morning and afternoon. The papers read before this division are listed here: "Developments in Blast Furnaces, Design and Practice," by Arthur G. McKee; "Ore Handling Bridges," Alexander C. Brown, Industrial Brown Hoist Corp.; "Oil Electric Locomotives in Steel Mill Transportation," by W. L. Garrison, Ingersoll-Rand Co.; "Alloy Steels in Iron and Steel Mill Equipment," by M. J. R. Morris, Central Alloy Steel Corp.; "Evolution of Drives for Mill Table Rollers," by K. W. Feller, Schloemann Engineering Corp.; "Distribution of Heat in Combustion Furnaces," by M. H. Mawhinney, Electric Furnace Co.; "Advantages of Producer Gas as a Fuel Compared with Other Forms of Fuel," by Victor Windett, Wellman-Seaver-Morgan Co.; "Powdered Coal Cupola," by D. H. Meloche, American Radiator Co.

The Eleventh Annual National Metal Exposition

Recent progress in the production, selection, fabrication, inspection, treatment and application of metals and alloys formed the background of the Eleventh Annual National Metal Exposition. More than 200 manufacturers exhibited machinery, furnaces, metals and alloys, testing machines, instruments, etc. The displays, which are most impressive either due to the number of manufacturers present or because they represented recent developments, were those devoted to welding, non-corrosive and heat resisting alloys, X-rays, instruments and tungsten carbide cutting tips.

Nitralloy

Particular attention was attracted to the engine and chassis of a Hispano-Suiza automobile displayed in the arcade by the Nitralloy Corporation of America. This car was displayed to illustrate the use of nitrided Nitralloy parts. The Nitralloy is used in the Hispano-Suiza car for cylinders, crankshafts, timing gears, water pump shafts, clutch disc, valve tappets, camshaft and gears, crankshaft vertical gears, oil pump gears, ignition shaft gears and screws and distributing shaft gears.



Non-Corrosive and Heat-Resisting Alloys

The displays of non-corrosive and heat-resisting alloys were very extensive. Heat resisting and corrosion-resisting Ascoloy and Allegheny metal, and semi-finished samples of these alloys were exhibited by the Allegheny Steel Company.

The Calorizing Company showed miscellaneous castings of Calite alloys used in heat treating: carburizing boxes, cyanide pots, hearth plates, rollers for continuous furnace operation, as well as calorized steel parts; oil still tubes, cyanide and salt pots, pyrometer protection tubes, etc.

At the booth of the Central Alloy Steel Corporation, large tool bits, seamless boiler tubes, Toncan copper molybdenum iron, Enduro Nirosta steel, Agathon Nitralloy and a Curtiss-type air-cooled aeroplane engine were shown.

The Chicago Steel Foundry Company exhibited chrome-nickel alloy castings: boxes, pots and furnace parts and sheet alloy fabricated parts for use at high temperature; and special high strength chrome-nickel castings.

Heat-resisting and acid-resisting castings, including carburizing pots and boxes, pusher grids and traps, rails, retorts and miscellaneous equipment for a large number of metallurgical operations were shown by the Chrobaltic Tool Company.

A display of corrosion-resisting articles was featured by the Crucible Steel Company of America. The Colonial Steel Company had available for inspection stainless iron and steel sheets, special forgings, copper-clad ground rods, plow steel, jail bar and safe steel, die blocks and mining drill steels.

METALS & ALLOYS

The Driver-Harris Company exhibited castings, retorts, carburizing boxes, pots, pyrometer tubes and furnace parts of Nichrome for heat resisting purposes; Nichrome B for addition to cast iron, Nichrome sheet carburizing containers and Nichrome wire for use as industrial furnace elements and other heat-resisting applications.

The Duraloy Company showed samples of various grades of alloys they manufacture, miscellaneous pipe fittings, cast impellers, hearth plate and rolling mill guides.

In the booth of the Duriron Company, their new Duriron centrifugal pump was operated to show the self-priming feature. A line of pipe fittings, a Durimet welded tank for pickling and Durimet in the form of sheet and bars was also shown.

The exhibit of the Electro Alloys Company consisted of Thermalloy castings of various types used in electric furnace construction and heat treating equipment.

The General Alloys Company's display was made up of Q-Alloy heat treating containers and furnace parts, carburizing boxes, hearth plates, roller rails, trays, muffles, Link-Belt chain for high temperature operation and point bars for vitreous enameling.

The Michigan Steel Casting Company showed Misco alloys in the form of castings, rolled bars, wire and sheets. A complete line of Lite-Wate Rezistal carburizing and annealing boxes; welded and seamless formed containers, also stampings of various grades of chrome and chrome-nickel alloys were on display in the booth of the Pressed Steel Company.

Rust-resisting and heat-resisting iron having the trade names Defirust and Defiheat, respectively, were on display in the booth of the Rustless Iron Corporation of America. The articles shown were automobile parts: hood hinges, running board moldings, lamp cases, and radiator shells; also bars, strip, sheets, wire and tubes.

The Ludlum Steel Company had a very extensive display of their products: Enduro K A2 steel in the form of plates, bars, wire and sheets, shown with pickled, brushed, stained and polished surfaces; wear-resisting, ammonia-hardened Nitralloy steel for sliding or rolling wear; tool steels and rustless iron and steel in finished forms.

LUDLUM STEEL COMPANY

The Standard Alloy Company showed Standardalloy lead pots, cyanide pots, normalizing and pack-heating furnace discs and spacers, enameling burning racks; chain grate castings, furnace trays and shoes, roller rails, pump castings and impellers, and miscellaneous heat and acid-resisting castings for the heat treating and chemical field.

A very interesting display was that of Wickwire Spencer-Steel Company. This consisted of a belt constructed of alloy wire, which traveled through on electric furnace operating between 1800 and 2000 degrees Fahrenheit, without serious oxidation and at the same time was sufficiently flexible to travel around small pulleys and resist distortion.

Tungsten Carbide Tool Tips

Tungsten Carbide cutting material was shown by five companies, in each case under their own trade name. In the booth of the Carboloy Company, Inc., a turret lathe equipped throughout with Carboloy cutting tools was operated at high production speeds on various materials. Carboloy tools of various shapes and styles were exhibited as well as Carboloy wire drawing dies. Cutting demonstrations with Dimondite were carried out in the booth of the Firth-Sterling Steel Company on a special lathe designed for operating exceptionally high speeds. A material of this character called Haystellite was exhibited by the Hanes Stellite Company. Strauss Metal, the tungsten carbide cutting material manufactured by the Ludlum Steel Company was on display. Widia tools were demonstrated cutting various materials at high speeds in the booth of Thomas Prosser and Son. Widia tipped lathe planer and shaper tools, drills, reamers, milling cutters, boxing and special tools were also shown.

Metals

Aluminum in the form of ingots, forgings, permanent mold castings, sand castings, die castings, bar aluminum, tubing conduit, pipe fittings, stream line tubing, foil, seals and caps, electrical conductors, collapsible tubes, extruded molding and structural shapes, shingles, gutters, flashings, corrugated roofing, radio parts, beams, window sash, carpet frames, doors, screw machine products, paint and bronze powder, welded chemical vessels, permanent mold cast and stamped cooking utensils, chairs, ladders, etc., was exhibited by the Aluminum Company of America. An interesting feature was the cast aluminum statue of Charles M. Hall. Magnesium wire and rod were also shown.

Molybdenum in all forms as desired by the iron, steel, chemical and dye industries was on display in the booth of the Climax Molybdenum Company.

The International Nickel Company, Inc., illustrated the widespread use of nickel in industrial application by means of display material.

The Vanadium Corporation of America exhibited ferro-vanadium, ferro-chromium, ferro-silicon, and other steel making alloys; ores, oxides; chemical compounds of vanadium, tungsten, molybdenum, chromium and other rare and semi-rare metals.

The display of the New Jersey Zinc Company included 40 die-castings of small and intricate design. It featured rolled zinc, chromium plated and nickel plated.

Welding

Welding equipment was grouped in one section of the exposition. In many cases the equipment was in operation and in practically all cases samples of welded work were exhibited. Among the companies displaying welding equipment were: Air Reduction Sales Company, Bastian Blessing Company, Elkon, Inc., Federal Machine & Welder Company, Fusion Welding Corporation, General Electric Company, Gibb Welding Machines Company, Harris Calorific Company, K-G Welding & Cutting Company, Lincoln Electric Company, Linde Air Products Company, Metal & Thermit Corporation, Northwestern Manufacturing Company, Taylor-Winfield Corporation, Torchweld Equipment Company, Una Welding & Bonding Company, Weldit Acetylene Company, Westinghouse Electric & Manufacturing Company and Williams & Company, Inc.

Welding wire was on display in the booths of the American Brass Company, American Steel & Wire Company, Haynes Stellite Company, Page Steel & Wire Company, Roebling's Sons Company, Stoody Company and Wickwire Spencer Steel Company.

Heat Treating and Melting Furnaces

Furnaces were in operation in the booths of the Ajax Electrothermic Corporation, American Electric Furnace Company, American Gas Furnace Company, Bellevue Industrial Furnace Company, Bellis Heat Treating Company, Eclipse Fuel Engineering Company, Falls Electric Furnace Corporation, General Electric Corp., C. I. Hayes, Inc., Mahr Manufacturing Company, McCann-Harrison Corporation, Sentry Company, Strong, Carlisle & Hammond Company, Surface Combustion Company, Inc. and Harold E. Trent Company.

Instruments and Testing Machines

The exhibits of metallographic and physical testing apparatus pyrometers and other measuring equipment aroused considerable interest.

Automatic temperature controllers were shown by the Automatic Temperature Control Company, Bristol Company, Brown Instrument Company, Case Hardening Service Company, Leeds & Northrup Company, Republic Flow Meters Company, and Wilson-Maeulen Company.

X-ray negatives and photographs of castings, showing internal flaws detected by X-ray examination were displayed in the booth of the Eastman Kodak Company, Kelley-Koett Manufacturing Company and Victor X-ray Corporation.

The Bausch & Lomb Optical Company featured a wide-field binocular microscope for the examination of opaque samples, a toolmaker's microscope, photomicrographic and projection apparatus, colorimeters and other optical measuring instruments. E. Leitz, Inc., also displayed laboratory and research metallographic equipment.

The Tinius Olsen Testing Machine Company demonstrated various types of testing equipment: Brinell hardness testers, Herbert hardness testers, universal testing machines and other testing devices. The Riehlé Bros. Testing Machine Company exhibit included a Brinell machine, calibrating rings and a mirror extensometer.

A 60,000 pound universal testing machine was in continuous operation, in the booth of the Southwark Foundry & Machine Company and the Steel City Testing Laboratory. Other equipment on display included a Brinell machine, a sheet metal tester, a strain gage and tensometer and the electric telemeter.

The Pittsburgh Instrument & Machine Company showed proving rings, sheet metal testers, hand and power Brinell Machines and an instrument attached to the Brinell machine, which indicates the ball impression diameter on a ground glass plate while the test is made. A variety of hardness testing machines were shown by the Shore Instrument & Manufacturing Company.

Birger Egeberg showed a new optical pyrometer, Chemical Rubber Company demonstrated an apparatus for the rapid determination of CO, and the Thompson Grinder Company exhibited a Moore fatigue testing machine.—Richard Rimbach.

Fifty-Sixth Meeting of the American Electrochemical Society, Pittsburgh, Pa.

In many respects the fifty-sixth meeting of the American Electrochemical Society held on September 19th, 20th and 21st was one of the most successful ever held by the Society—the registration was over 250. The technical sessions, the smoker and the banquet were well attended and much credit is due to the Pittsburgh committee members for their untiring efforts and the very excellent arrangements.

The forenoon sessions of the convention were devoted to the reading of technical papers and the afternoons to plant visits. On Thursday afternoon the members of the society visited the Arnold plant of the Aluminum Company of America, where they saw the melting and casting of ingots, hot and cold rolling, extrusion of tubes and various other shapes, annealing and heat treating, and the manufacture of foil and seals, bottle caps, etc. Friday afternoon the members were offered the opportunity of visiting any of the following plants: East Pittsburgh plant of the Westinghouse Electric & Manufacturing Company, the McKeesport plant of the Firth-Sterling Steel Company, the Braddock plant of the Carnegie Steel Company, the Colfax Station of the Duquesne Light Company, two electro-plating plants: Walter Hague Company and National Casket Company.

The first technical session was devoted in part to the "Contributions of Electrochemistry to Aeronautics." Dr. J. D. Edwards presided at this session.

The papers devoted to aeronautics were: "Aluminum and Its Alloys in Aircraft," by T. W. Bossert, Aluminum Company of America; "Magnesium and Its Alloys in Aircraft," by W. G. Harvey, Aluminum Company of America; "Note on the Possible Use of Beryllium in Aircraft Construction," by Dr. H. W. Gillett, Battelle Memorial Institute; and a moving picture film on the Metal Clade Airship was shown through the courtesy of the Detroit Aircraft Corporation. A number of the members present took part in the discussion of these papers: Mr. Warner, Editor of Aviation; Dr. Lewis and Mr. Truscott of the National Advisory Committee for Aeronautics; Dr. Blum, U. S. Bureau of Standards; Mr. Cone, Editor of *Iron Age* and others.

Several other papers were read at this session: "Solution Potentials of Aluminum Alloys in Relation to Corrosion," by Dr. J. D. Edwards and Cyril S. Taylor, Aluminum Company of America; "Lime Process for Coating Aluminum," by Leon McCulloch, Westinghouse Electric & Manufacturing Company; "Magnetic Susceptibility of Aluminum," by Dr. Ralph B. Mason, Aluminum Company of America; "Thermo-Electric Tests for Aluminum-Manganese and Other Alloys," by C. S. Taylor and Dr. J. D. Edwards; "Oxygen and Hydrogen in Industry," by W. P. Dobson and A. S. L. Barnes, Hydro-electric Power Commission, Ontario; "Muscle Shoals Relative to Conservation," by Farley G. Clark, Toronto.

Two parallel sessions were held on Friday morning one under the auspices of the Electrothermic Division at which Harry M. St. John presided, the other a reading of miscellaneous papers, at which Dr. Francis C. Frary presided.

The first paper before the Electrothermic Division, "The Design and Operation of Vacuum Furnaces with Carbon Resistor Tubes," by Arthur S. King, Head of the Physical Laboratory, Mount Wilson Observatory, Pasadena, Calif., was read by Dr. Fink in the absence of the author. This paper, illustrated by means of lantern slides, described two types of electric vacuum furnaces in detail. These furnaces are the result of years of study on rendering metallic vapors luminous by "temperature radiation." The furnaces have a temperature range up to 3500° C., and steady conditions of temperature and pressure are quickly reached, after which the light is permitted to pass to the spectrograph.

A new low frequency inductive furnace was described by Dr. Brace, Westinghouse Electric & Manufacturing Company. This furnace operates on 220 volts, 60 cycle, single phase current and can be built in sizes as small as 60 pounds capacity.

An informal discussion, "Recent Developments in the Annealing of Non-Ferrous Metals," was then introduced by Robert M. Keeney, Connecticut Light and Power Company.

The following papers were read at the miscellaneous Papers Session:

"Hydrolysis of Mercurous Sulphate by Cadmium Sulphate Solution in the Weston Normal Cell," by W. Cecil Gardiner and George A. Hulett, Princeton University.

"Oxidation of the Depolarizer in Preparing Standard Cells," by W. Cecil Gardiner and George A. Hulett, Princeton University.

"Crystalline Mercurous Sulphate and the Weston Normal Standard Cell," by Donald B. Summers and W. Cecil Gardiner, Princeton University.

"Studies of Over-Voltage on Metals," by P. Sederholm and Carl Benedicks, Metallografiska Institute.

"The Electrical Conductivities of Ammonia-Water Mixtures. Between 26 and 82 Percent Ammonia and from −30° to +30° C.," by M. deKay Thompson and R. B. Atkinson, Mass. Institute of Technology.

"On Simple Methods of Potentiometric Titration of Acids and Bases," by Louis Kahlenberg and Albert C. Krueger, University of Wisconsin.

"On the Road to Pure Iron and Some of Its Indicated Properties," by T. D. Yensen, Westinghouse Electric & Manufacturing Company.

"Recent Developments in the Analysis of Carbon in Iron and Iron Alloys," by N. A. Ziegler, Westinghouse Electric and Manufacturing Company.

"Rate of Corrosion of Ferro-Nickel Alloys," by Colin G. Fink and Claude M. Decroly, Columbia University.

"Accelerated Corrosion Tests for Coatings of the Iron Phosphate Type," by E. M. Baker, A. J. Herzig and R. M. Parke, University of Michigan.

The Saturday morning sessions were divided as follows: Session A in charge of the Electrodeposition Division, Dr. Charles L. Mantell, presiding; Session B in charge of the Committee on Electro-Organic Chemistry, Dr. Frances C. Frary presiding.

The papers at Session A are listed here:

"The Measurement of the pH of Nickel Plating Solutions," by Wm. Blum and N. Bekkedahl, Bureau of Standards.

"Insoluble Sulphates and Passivity," by Leon McCulloch, Westinghouse Electric and Mfg. Co.

"The Determination of Sulfate in Chromic Acid and in Chromium Plating Baths," by H. H. Willard and Richard Schneidewind, University of Michigan.

"A Convenient Method for the Determination of the Sulfate Content of Chromium Plating Baths," by Lawrence E. Stout and A. W. Petchaft, Washington University.

"Some Chromium Plating Experiments," by Chester M. Alter and Dr. Frank C. Mathers, Indiana University.

"Hardness of Electrodeposited Chromium," by Dr. Robert J. Piersol, U. S. Chromium Corporation.

"Electrode Potentials of Copper Anodes and Copper in Copper Cyanide-Sodium Cyanide Solutions," by George M. Smith and J. M. Breckenridge, Vanderbilt University.

"The Use of Tantalumas Cathode for the Electrodeposition of Copper," by Lester W. Strock and Hiram S. Lukens, University of Pennsylvania.

Critical Abstracts

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts of a critical nature on articles of special importance. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

The Effect of Aging and of "Blue-Brittleness" on the Toughness of Low-Carbon Steel*

By A. Kühle

As indicated by the title, Kühle's investigation was concerned principally with the effect of aging and of "blue-brittleness" on the toughness of low-carbon steel as measured by the repeated blow impact test; in addition, however, he employed, as a comparative method, the more commonly used notched bar impact (single-blow) test. Beginning with Bauschinger,[1] whose pioneer paper appeared in 1886, Kühle's predecessors in the study of this important and still-puzzling phase of metal technology have investigated, for the most part, the effect of aging and allied phenomena on the more usually commercially determined properties of tensile strength, ductility, elasticity, etc.; only a comparative few—and these confined mainly to Kühle's countrymen—have utilized the dynamic impact test as a method of evaluating the toughness of strained and subsequently aged (natural and accelerated) materials. One recalls, in this connection, such names as Welter,[2] Rittershausen and Fischer,[3] Preuss[4] and others.

Kühle's work was done on two steels, designated A and B, having the following composition and properties:

Chemical Composition
(In Percent)

	C	Si	Mn	P	S
Steel A	0.08	0.01	0.34	0.02	0.05
Steel B	0.07	0.01	0.39	0.09	0.08

Physical Properties

	El. Limit (Kg./Mm.^{2})	T. S. (Kg./Mm.^{2})	Elong. (%)	Red. Area (%)
Steel A	28.5	36.5	38.2	64.3
Steel B	32.7	44.5	22.9	53.2

A practical difference in the two steels is the higher sulfur and phosphorus content of steel B. This difference in chemical composition is reflected in the higher tensile strength and elastic limit, and lower ductility of steel B, and, according to Kühle, in the latter's greater susceptibility to aging—an opinion shared, in the case of the phosphorus at least, by Stromeyer.[5]

Previous to carrying out the procedure given below, both steels were normalized (at 950° C. for one-half hour and cooled in air), and then cut into rods 320 mm. long, a length sufficient to give one tensile and one impact specimen. These rods from each steel were divided into four groups, three of which were cold worked by stretching to 2.5, 5 and 10 percent of their respective original lengths. The fourth group was left unstrained.

Kühle studied first the susceptibility to natural aging of the two steels, using the following plan: from the four groups of each of steels A and B, three test pieces for single impact and three for repeated impact testing were taken for each of the following conditions: (1) test immediately after deformation, (2) test 1 day after, (3) test 10 days after, (4) test 100 days after, and (5) test 300 days after. The results are given in Figures 1–4. In Figures 1 and 2 are given the results of the repeated impact test. The repeated impact number of steel A (low sensitivity to aging) is raised some 45% by cold working. Aging one day results in a loss of about one-half the increase with a slight rise again to 300 days, the impact value, however, remaining always above that of the unworked steel. The latter, during the same period of aging, increases its impact value some 20%.

The repeated impact number of steel B is also raised by cold stretching, the maximum increase (110%) occurring with the 10% deformed bars. The values of all worked bars decrease on aging; in no case, however, does the aged value fall below that of the unworked steel. Unlike steel A, steel B in the unstrained condition shows an impact value not greatly changed during the 300-day period.

A still greater difference than the foregoing is the marked rise in impact number of steel B by the cold working, and the greater variation in this value by the different degrees of working employed. This large change (increase) in impact strength produced by cold working of this high phosphorus steel indicates the probable influence of this element on impact toughness. It is known that phosphorus raises the resistance to deformation in the cold[6] (compare also, in this connection, the elastic limits of the two steels), and Rittershausen and Fischer[7] report that the values in the repeated impact test parallel those found for the elastic limit. It is quite possible that the change in impact resistance with cold working, or with cold working plus aging, may in some way be tied in with elastic properties. It is certainly true that the latter properties are, in a major way, affected by aging.[8]

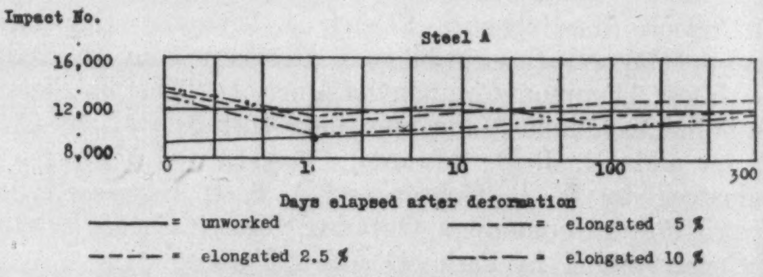


Figure 1—Repeated Impact Test

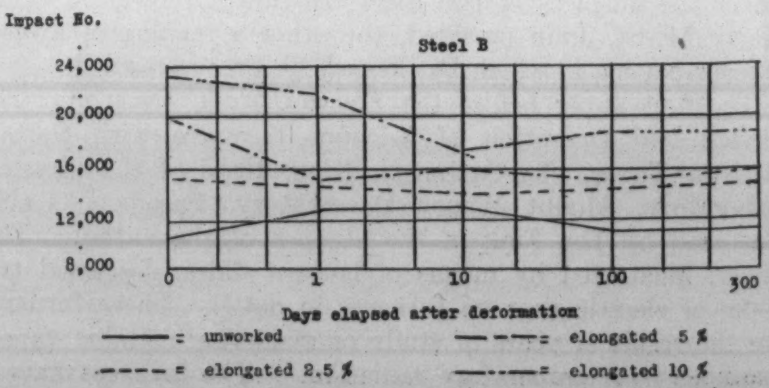


Figure 2—Repeated Impact Test

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* Mitteilungen aus dem Forschungs-Institut der Vereinigte Stahlwerke Aktiengesellschaft Dortmund, Band1, Lieferung 4, 1929.

[1] Bauschinger, *Mitt. d. mech. techn. Labor. d. K. T. H.*, München (1886).

[2] Welter, "Dauerschlagfestigkeit und dynamische Elastizitätsgrenze," *Zeits. Verein deutscher Ing.*, **70** (1926).

[3] Rittershausen und Fischer, "Dauerbrüche an Konstruktionstählen und die Kruppsche Dauerschlagprobe," *Kruppsche Monatshefte*, **1** (1920).

[4] Preuss, "Kerbwirking bei Dauerschlagbeanspruchung," *Zeits. Verein deutscher Ing.*, **58** (1914).

[5] Discussion by Stromeyer of "Notched Bar Impact Tests," Greeves and Jones, *Jour. Brit. Iron and Steel Inst.*, **112**, 2, p. 163.

[6] Oberhoffer, "Das technische Eisen," 2, Aufl. (1925).

[7] Rittershausen und Fischer, *loc. cit.*, page 93.

[8] See, for example, "The Effects of Cold-Working on the Elastic Properties of Steel," van den Broek, *Carnegie Scholarship Memoirs*, **8-10**, 125 (1917–20).

It is worthy of note that none of the aged specimens, worked or unworked, shows a lower impact strength than the unworked, unaged steel.

Figures 3 and 4 show the effect of cold deformation and subsequent aging on the toughness of the two steels as determined by the single impact test. In the first place, one notes that aging has little influence on the toughness of the unstrained bars. Cold working, without aging, slightly increases the toughness of the lesser strained steels while markedly lowering that of the one strained 10%. This observation holds for both steels. Aging after the cold work results in a lowering of the toughness between the 10th and the 100th days of approximately 70% in the case of steel A irrespective of degree of strain; with steel B, aging also results in a decrease of toughness but here the main decrease takes place between the 1st and the 10th days and the decrease furthermore is roughly proportional to the degree of strain, that is, the most severely strained bars show the greatest decrease, etc.

A comparison of the two sets of curves shows (1) that with either steel A or B, cold deformation (in tension), up at least to 10% elongation, initially raises the repeated impact strength, whereas deformation of that degree causes a marked drop in single impact toughness, and (2) that aging after deformation results in a decrease in both the repeated and single impact values.

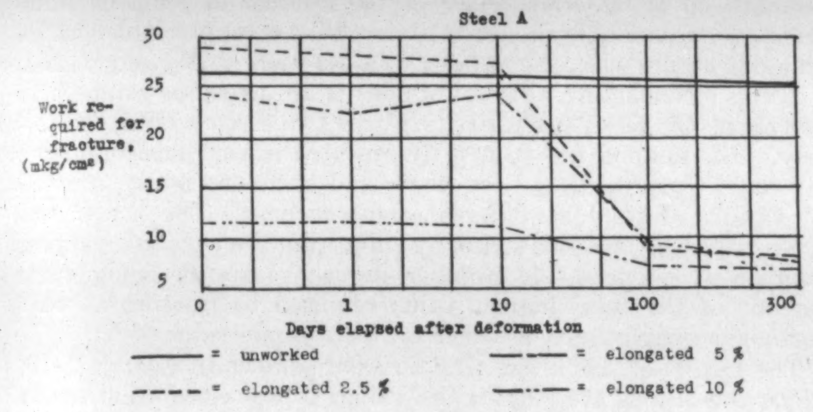

Figure 3—Single Impact Test

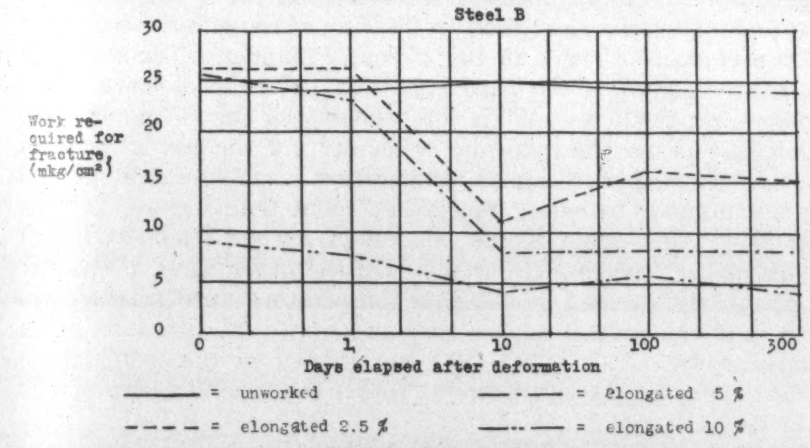

Figure 4—Single Impact Test

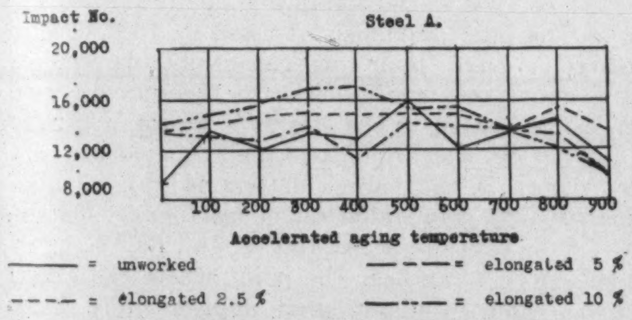

Figure 5—Repeated Impact Test

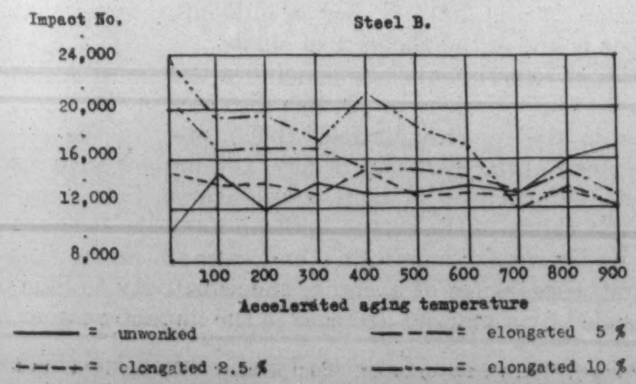

Figure 6—Repeated Impact Test

Kühle also investigated the behavior of both steels when aged artificially, that is, when heated for one hour at temperatures above room temperatures. The results of this series are given in Figures 5–8, and represent, as in the previous series, the average of three close values, the maximum deviation from the mean in no case exceeding ±7%. The effect of accelerated aging on the repeated impact strength of steel A (Figure 5) is to raise the strength (both for the unworked and for the worked bars) with increasing aging temperatures to a maximum occurring at 300–500° C., the greatest increase taking place (in the case of the worked bars) in the one most severely (10%) deformed. Above 400–500° C. the impact number drops, probably due, as Kühle states, to recrystallization beginning at these temperatures. Despite the drop at 400–500° C., it is interesting to see that the impact strength of all the stressed bars at 800° C. is well above that of the unworked steel; as a matter of fact, the lowest value at that temperature—that of the bar elongated 10%—is around 32% higher than the original impact value. It would appear from these results that grain growth, which should be well advanced at 800° C.,[9] has no serious deleterious effect on repeated impact strength. This quite agrees with the conclusions of Schulz and Püngel,[10] but not with those of Mailänder.[11] If, as Rittershausen and Fischer[12] found, there is a parallel relationship between the elastic limit and the repeated impact strength, then the rise in impact resistance in the blue heat temperature range occasions no surprise.

The somewhat erratic behavior of the unstrained bars (their curves, however, showing a well-defined maximum at 500° C.) Kühle ascribes to surface cold working of the specimens during the test.

The repeated impact-temperature curves (Figure 6) of the accelerated aged bars of steel B show quite different characteristics from those of the foregoing. First, the highest impact values are found in the worked, unaged bars. The impact strength falls off with increasing aging temperature, with the most severely deformed (with the highest initial value) decreasing most rapidly. At about 700° C. all worked bars have the same impact strength which is about 15–20% above that of the unworked, unaged steel. All of the deformed specimens show here a maximum in their curves at 800° C.; in steel A this was true only of the least strained bar.

The effect of accelerated aging on the single impact toughness of the two steels is shown in Figures 7 and 8. Heating both strained steels (including all three degrees of strain) results in a minimum value for toughness at about 200–300° C. While the decrease is not so pronounced in the case of steel A as with steel B, there is a decided brittleness in single impact toughness of both in

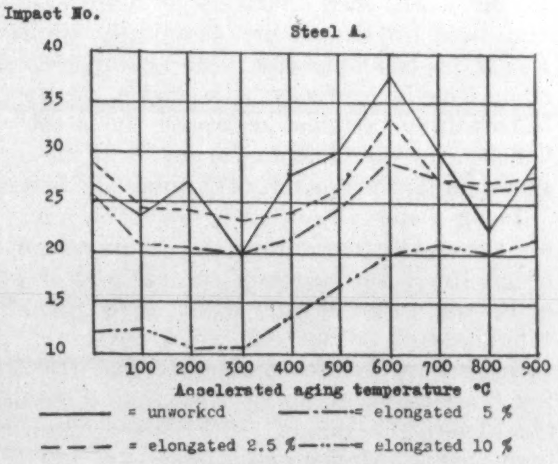

Figure 7—Single Impact Test

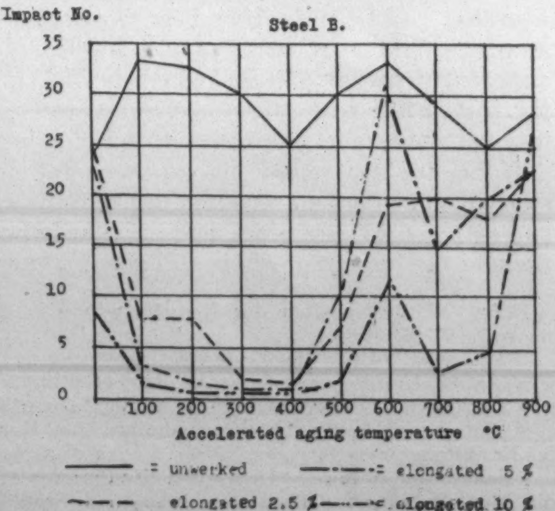

Figure 8—Single Impact Test

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[9] Oberhoffer, *loc. cit.*, page 373. Compare, however, McAdam, "Grain Size of Iron as Affected by Temperature," *A. S. T. M.*, **18**, Pt. II, *Tech. Papers*, pages 68–86 (1918).

[10] Schulz und Püngel, "Erholungspausen, Temperatur, Korngrözen und Kraftwirkungslinien bei der Dauerschlagprobe," *Ber. Werkstoffausschuss V. d. Eisenh.*, Nr. 40.

[11] Mailänder, "Ermüdungserscheinungen und Dauerversuche," *Ber. Werkstoffausschuss V.d. Eisenh.*, Nr. 19.

[12] Rittershausen und Fischer, *loc. cit.*, page 93.

this temperature range. The curves rise from the minimum to a maximum at 600° C.—again, a common behavior of both steels—which Kühle interprets to be the point of incipient recrystallization and hence of some effect on the toughness. The minimum occurring at 700–800° C. is unexplained, but it may be tied in with grain growth phenomena.

The minimum values for steel A (Figure 7) in the 200–300° C. (so-called blue heat) range, ranging from slightly above 10 mkg./cm.^{2} for the 10% stressed bars to about 20 mkg./cm.^{2} for the bars deformed to a less degree, Kühle thinks still too high, and suggests that the relatively high toughness of this steel at these temperature may be peculiar to steel of this composition. This may well be since Fry[13] in 1926 reported a low-carbon steel (with somewhat lower phosphorus and sulphur than this steel), viz., Izett steel, which was not susceptible to aging. This is further borne out by the fact that steel B (Figure 8) with a high sulphur and phosphorus content is more brittle when aged artificially in the 300–400° C. range.

Summarizing and comparing Kühle's results of his tests on the repeated and single impact toughness of the two steels, cold worked and subsequently aged, naturally and artificially, one notes (1) that the repeated impact test shows no evidence of brittleness developed by accelerated aging at the well-known optimum "blue heat" temperatures, *when the test is carried out at room temperatures*, whereas the single impact test reveals a pronounced brittleness in strained steels subsequently heated to these temperatures, (2) that the repeated impact test shows but a relative small loss of toughness in strained steels subsequently aged for 1, 10, 100, etc., days, both the aging and the testing taking place at room temperatures, while the single impact test indicates a pronounced loss in toughness on aging at ordinary temperatures, (3) that with steel A, a 300-day aging period does not give a repeated impact value as large as that resulting from one hour's heating at 200–300° C., while in the case of steel B it does, and (4) that the single impact toughness of steel A shows a greater decrease on aging 100 days than on the heating to 100–300° C., while with steel B the reverse is true.

An interpretation of the differences noted is difficult. Obviously, it is to be sought in the difference of the two testing methods—a difference that perhaps one should expect from the known dissimilarities of other static and dynamic testing methods. If one holds with Fettweiss,[14] Jeffries,[15] and others that aging and blue brittleness are essentially similar phenomena, one is forced to conclude from (3) above that a considerably longer aging time is necessary with steel A than with B in order to reach the maximum attainable through the use of an accelerant (heating). On the other hand, from the results of the apparently more reliable single impact test, as in (4) above, one is not so sure of this.

Using a specially constructed furnace and an ingenious method for accurately measuring the temperature of the trough of the notch (both variations of the method of Müller and Leber, and of Schulz and Püngel), Kühle investigated the repeated impact toughness of both steels when measured, not a room temperatures, but at elevated temperatures. He found a maximum value for both steels at about 210–220° C., and consequently within the blue-brittle range. Kühle's maximum is considerably higher than that of Müller and Leber[16] (= 150° C.), or that of Schulz and Püngel[17] (= 175° C.), an anomaly of the repeated impact test that had been explained by Oberhoffer[18] as due to the speed at which the test is carried out. Kühle's more accurate work has apparently made this apologia superfluous, and to have brought the test in line with other mechanical testing methods as showing marked changes in properties in the blue heat range.

Kühle further varied his experimental procedure to include a study of the effect on repeated impact strength of aging (naturally and artificially) bars which had previously been stressed by placing them in the impact machine and given a varying number of blows, the exact number in each case being a definite percent of those previously determined as necessary to cause fracture. This number at room temperature, i. e., at 20° C., was designated N_{20}. The results of the natural aging test are practically the same, qualitatively and quantitatively, for the two steels. After aging 50 days, the least-hammered bars ($^1/_{10}\ N_{20}$ and $^1/_5\ N_{20}$) show an increase of twenty percent in impact number. The medium stressed bars ($^1/_4\ N_{20}$ and $^1/_3\ N_{20}$) show no rise during the same period, while the bars of maximum stress ($^1/_5\ N_{20}$ and $^3/_4\ N_{20}$) show a slight rise. The corresponding bars aged for 100 days parallel in direction and equal almost in value the above.

A companion series of bars of the two steels, stressed as before to $^1/_{10}\ N_{20}$, $^1/_5\ N_{20}$, etc., aged 50 and 100 days, respectively, was then heated in an oil-bath for one hour at 250° C. and the bar fractured in the repeated impact machine. The results again parallel those above, with perhaps those bars aged for the longer period showing the least gain.

The results reported here are not in agreement with those given by Schulz and Püngel,[19] who claim an improvement in impact strength on aging, irrespective of the number of previous blows given, whereas Kühle shows, as above, that no appreciable change on aging occurs when the number falls between $^1/_5\ N_{20}$ and $^1/_3\ N_{20}$.

Kühle's concluding series of studies is an ingenious attempt to determine the relative sensitivity of the two steels to blue-brittleness. His method was to test by repeated impact measurements (at room temperatures) bars which had been previously stressed to various degrees at different temperatures. The stress was given, as in the previous series, by subjecting the bars to a varying number of impacts, the number in each instance being some percent of the total impact value required to fracture at that particular temperature, in other words, to some value of N_t.

The results of this interesting series are shown in Figures 9–10. Along the X-axis are plotted the values of the previous stress in terms of N_t, that is, the fraction of the total blows necessary for fracture at the temperature in question; on the Y-axis are given the impact numbers required to fracture at room temperature the bars previously stressed in the aforesaid manner. The solid line in each diagram is the experimentally determined curve. The broken straight line at 45° is the "theoretical curve," determined by Kühle as per the following reasoning: if the bar is not previously stressed at a higher temperature it will require the full impact number to cause fracture at room temperature, that is, 100 N_{20}. This value Kühle has taken as one (the left hand) point on his "theoretical curve." On the other hand, if the bar is previously stressed at a higher temperature until fracture ensues, it obviously will require zero impacts to fracture it at room temperatures. This value (100 N_t, where t = the temperature of the previously applied stress) forms the second point of the "theoretical curve."

In Figure 9 (for steel A) one finds that the experimental curve for the bar stressed at 100° C. is practically identical with the theoretical curve. The bars previously stressed at 150° C. and 200° C., respectively, have their experimentally determined curves lying partly above and partly below the theoretical curve. In each diagram, a line normal to the X-axis is shown, generally between 0.4 N_t and 0.6 N_t, which indicates the first evidence of a crack or fracture fissure in the bar as determined by metallographical examination of a companion set of test bars. The experimental curves for the bars stressed at 150° C. and 200° C. intersect the theoretical curve at or near the point where the above line also crosses it. Thus, the measured impact value drops below the theoretical value when the first crack appears. The experimental curve for the 250° C. bar is indefinite, while that of the 300° C. bar is above the theoretical curve.

From this series of experiments one concludes that steel A has some sensitivity to blue-brittleness. Kühle also sees in the result a dual character in the repeated impact itself, first, in the circumstance that, until initial fissuring occurs, the impact value is raised by previous deformation at high temperatures, thus paralleling results of the values of the elastic limit and tensile strength of like material under similar conditions, and, second, in the fact that with the first appearance of a crack, the sensitivity to blue-brittleness is revealed by a marked decrease in the impact number.

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[13] Fry, "Das Verhalten der Kesselbaustoffe in Betrieb," *Kruppsche Monatshefte*, **7**, 185 (1926).

[14] Fettweiss, "Über die Blaubrüchtigkeit und das Ältern des Eisen," *Stahl u. Eisen*, **39**, 1 (1919). Also, *loc. cit.*, **42**, 744 (1922).

[15] Jeffries and Archer, "Science of Metals," page 182.

[16] Müller und Leber, "Beanspruchungshöhe, Korngröze und Temperatur bei Ermüdungserscheinungen," *Zeits. Verein deutscher Ing.*, **67**, 358 (1923).

[17] Schulz und Püngel, "Ueber den Einfluss des Alterns und Anlassens auf die Festigkeitseigenschaften von gezogenen Stahldrahten," *Ber. Werkstoffausschuss Verein d. Eisenh.*, Nr. 100.

[18] Oberhoffer, *loc. cit.*, page 397.

[19] Schulz und Püngel, "Erholungspausen, Temperatur, Korngrözen und Kraftwirkingslinien bei der Dauerschlagprobe," *Ber. Werkstoffausschuss Verein d. Eisenh.*, Nr. 40.

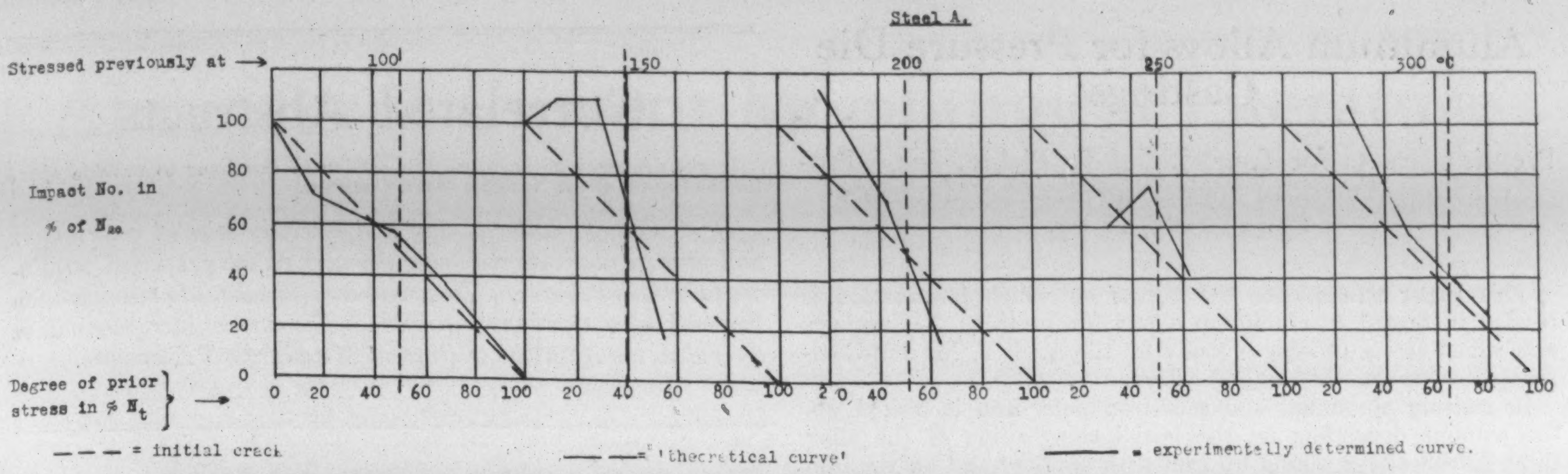

Figure 9—Impact Numbers at Ordinary Temperatures in Percent of N_{20} of Bars Previously Stressed at Higher Temperatures

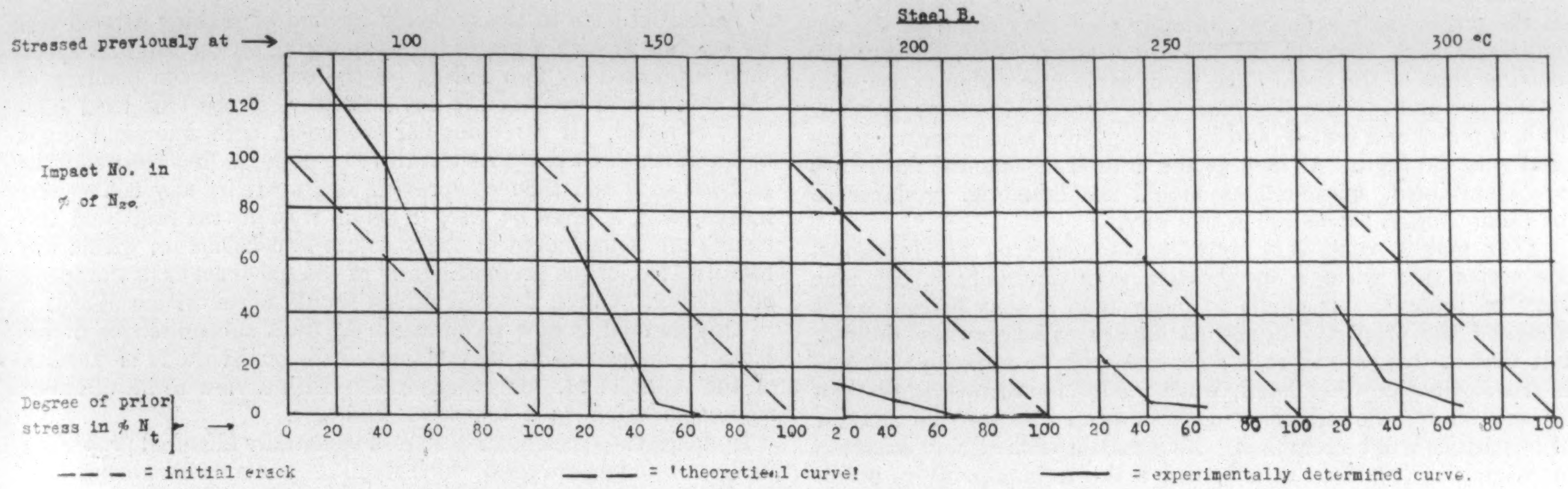

Figure 10—Impact Numbers at Ordinary Temperatures in Percent of N_{20} of Bars Previously Stressed at Higher Temperatures

One sees here a confirmation of the results of Preuss,[20] who some years ago found a marked decrease in repeated impact number in steel that had been stressed at 200° C. to 300° C. previous to the testing at room temperatures.

The companion set of curves for steel B is given in Figure 10. Here the determined curve runs well above the theoretical for the steel stressed at 100° C. prior to testing, while those steels stressed at higher temperatures have their determined curves lying below. The method, used in the above for the detection of initial cracking, failed to be of use here in this more brittle steel, hence no vertical line appears in the diagrams. Steel B shows brittleness in the blue heat range with all fractional values of N_t, whereas steel A showed a marked decrease in toughness only in the cases of the higher degrees of previous strain. Steel B is evidently much more sensitive to blue-brittleness than is steel A, a conclusion reached earlier with other testing series.

Because of the apparent sensitivity of the above test for the detection of susceptibility to aging, a single test was made on the aforementioned, so-called non-aging Izett steel. This was stressed at only one temperature previous to the test, viz., 250° C. The experimentally determined curve with the theoretical curve is given in Figure 11. The position of the determined curve well above the theoretical indicates that Izett steel is particularly non-sensitive to aging, if this test is a reliable criterion of such sensitivity, and from theoretical considerations it appears to be.

A summary of all the foregoing gives the following picture: steel A has at normal temperatures a repeated impact number of 12,910 (= N_{20}), and steel B one of 10,532. From microscopic evidence, the first crack appears in steel A at about 0.60 N_{20}; the material thus endures about 7750 impacts prior to initial fissuring. Like means failed to definitely locate a similar point in steel B, but from other evidence Kühle places it at only about 500 impacts below actual rupture, that is, at about 10,000 impacts.

Before the appearance of the first crack, the repeated impact number is proportional to the elastic limit and to the tensile strength. If one calculates from the known mechanical properties (see table, page 172) the "Stribeck coefficient"[21] of the two steels, one arrives at 18.5 as the coefficient of A and 22.0 as the coefficient of B. The ratio of these two numbers is approximately the same as that of the repeated impact numbers of the two steels up to initial fissuring—again, an apparent indication that up to that point the repeated impact number parallels the values for elastic limit and tensile strength.

As soon, however, as the first crack appears a complete change in the character of the test takes place; from that point on it simulates in its mechanism the single impact (notched bar) test. The repeated impact value now becomes primarily dependent on the sensitivity of the material to the "notch effect," or on its notch brittleness. This, i. e., notch brittleness, as determined by the single impact test, of steel B is greater than that of steel A (see Figures 4 and 5); thus it fractures much more rapidly after initial cracking than does steel A. There is, however, even here no observed relationship between the repeated impact number and the notched bar toughness.

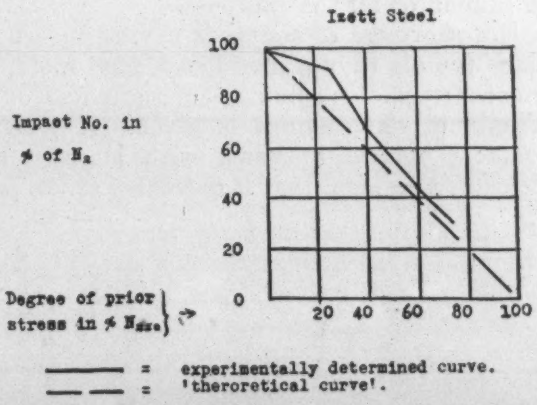

Figure 11—Impact Numbers at Ordinary Temperatures of Bars Previously Stressed at 250° C.

The often contradictory and puzzling results of the repeated impact test, so well brought out by Kühle's study of its application here in the study of aging and of blue brittleness, is apparently explained by the changes taking place during the progress of the test in the test specimen itself.—L. R. van Wert.

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[20] Preuss, "Kerbwirkung bei Dauerschlagbeanspruchung," *Zeits. Verein deutscher Ing.*, **58**, 701–704 (1914).

[21] Stribeck, "Dauerfestigkeit von Eisen und Stahl bei wechselender Biegung, verglichen mit den Ergebnissen des Zugversuches," *Zeits. Verein deutscher Ing.*, **67**, 631–636 (1923).

Aluminum Alloys for Pressure Die Castings

Preprint No. 51 for Tour, S. (of L. Pitkin, Inc.) Proceedings American Society for Testing Materials 29 (2) 1929, 18 pp.

This paper summarizes the points on which information is needed in regard to aluminum alloys for pressure die castings, and which are in process of study by the A. S. T. M. Sub-Committee on Die Cast Metals and Alloys.

In melting aluminum alloys in iron pots, iron is picked up, the amount depending on the initial composition of the alloy (high silicon alloys taking up iron with avidity) and on the iron already present. The dies are also attacked, an alloy low in iron attacking them much more rapidly than one with 1$^1/_2$ to 2% Fe. If the pot is badly attacked, an alloy scale may come off the pot and form hard spots in the finished casting, which destroy the cutting edge of the tool. The permissible iron range varies with conditions and is controlled practically by varying the proportions of new metal and remelt, and by adding pure aluminum when the iron gets too high. As long as the desired mechanical properties are maintained, specifications should not limit the producer so he cannot juggle his charge in this way.

Tour makes some very sensible comments on specifications. He states that when a specification says that only 0.75% zinc may be present, this ought to mean that if that percentage is exceeded the properties of the casting are no longer those desired, but that in this case there is no information to indicate that this is true. On the other hand, when 0.30% impurities other than Fe and Zn are allowed, that ought to mean that such an amount of impurities will be harmless. As a matter of fact, tiny amounts of magnesium, 0.05 to 0.10%, will make it impossible to polish the casting properly.

Too many specifications are drawn up as a result of the committee charged with making the specification becoming tired out and writing a specification just to get it off their hands. If all specifications were drawn on the basis of exact engineering knowledge of the reason for each limit set, and if people refrained from making specifications till they did have such knowledge, we would have fewer specifications, but those we do have would be more useful, and more used. Tour's comments are, therefore, very much to the point.

He emphasizes the fact that very little is known quantitatively about the solidification shrinkage of the alloys. The American Foundrymen's Ass'n is studying methods for determining solidification shrinkage, having placed a Research Associate at the Bureau of Standards for that purpose.

Hot-shortness of course is a vital defect in a die-casting alloy since the die cannot give like a sand mold, and the casting itself must stretch. A summary of the effect of different elements in aluminum die castings is given. A + sign indicates that the property named increases with increase in percentage of the element, a — sign, that it decreases as the percentage increases.

Element	Fluidity	Shrinkage	Attack on Iron	Hot Shortness	Strength at Elevated Temps.	Machinability	Polishing Properties	Plating Properties
Cu	+	−	−	−	+	+ to −	+	+
Si	+	−	+	−	+	0 to −	−	−
Fe	−	− to +	−	− to +	+	+ to −	+	+
Ni	−	− to +	−	−	+	+ to −	+	+
Zn	+	+	0	+	−	+	−	−
Mn	−	−	−	−	+	+ to −	+	0
Mg	−	+	0	+	−	−	−	−
Sn	+	+	−	+	−	+	−	−

H. W. Gillett.

Correlated Abstracts

It was necessary to condense this section in this issue to provide space for the reports of the National Metal Congress.

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts reviewing the work recently reported pertaining to certain subjects. These reviews will take into consideration the work of a number of workers. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

Bend Testing

Kinzel[1] objects to the ordinary method of making a bend test by bending around a pin or by a tup acting on the top of a specimen supported by two rollers, on the basis that the bending of the constrained specimen is not a measure of the true local ductility of metal. If a rectangular specimen, with smoothed edges and a width three times its thickness or more, is first bent slightly at both ends and then compressed as a strut by any convenient means, as in a press or vise, it bends without restraint and the results are independent of the absolute dimensions or, within the limits stated, of the geometric form of the specimen or of the speed of bending. Check determinations should agree within ±5%.

This method is now recommended,[2] by a subcommittee under Kinzel's chairmanship, to the Committee on Methods of Testing of the A. S. T. M. for consideration with a view to its ultimate recommendation as a tentative standard.

Homogeneous specimens of steel of essentially identical properties in the tensile test are cited which give 125% outside fiber elongation in the free bend test and 34%, respectively. The Izod values are, respectively, 49 and 6 ft. lbs. Either the free bend or the impact test differentiates between the steels, though there is no detectable difference in ductility in the tension test.

The method was especially developed for testing welds. The gage length for measurement of fiber elongation should be 0.3 to 1.0 inch save that in plate $^1/_4$ to $^1/_2$ inch thick the gage length should not be over twice the thickness. So far, the method is not recommended for material less than $^1/_4$ inch thick. Measurement of final distance between gage marks may be made by a flexible scale or with a special extensometer, described in the A. S. S. T. paper but not in the A. S. T. M. report.

The end point is failure in the outside fiber.—H. W. Gillett.

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[1] Kinzel, A. B. (Union Carbide & Carbon Laboratories), "A Critical Study of the Bend Test as Applied to Iron and Steel," *Trans. Am. Soc. for Steel Treating*, **12**, 778–1 (1927).

[2] Report of Section on Bend Testing of Committee (E-1) on Methods of Testing. Am. Soc. for Testing Materials, *Preprint* No. 4, 1929, for publication in *Proceedings A. S. T. M.*, **29**, pt. 1, 6 pages.

Dr. Anson Hayes has been appointed Director of Research, American Rolling Mill Company, Middletown, Ohio.

I. E. Waechter was made General Superintendent, L. N. N. Foundry Company, Cleveland, Ohio. He was formerly Superintendent of the Illinois Foundry Company, Springfield, Ill.

W. J. Beck, for 19 years Director of Research, American Rolling Mill Company, Middletown, Ohio, has been appointed assistant to the general manager. He will have direct charge of the development of electrical sheets.

Dr. A. E. R. Westman has resigned as Associate Professor of Ceramics, Rutgers University, to join the staff of the Ontario Research Foundation, Ontario, Canada.

Abstracts of Current Metallurgical Literature

In this section, there will each month appear brief abstracts of articles in the metallurgical field appearing in various publications. These abstracts are not critical, but merely review developments as they are recorded. Every effort will be made to report on all articles as soon as possible. Beginning with this issue the abstracts are arranged according to subject.

PROPERTIES OF METALS

Solubility of Metals in Milk. G. N. Quam. *Industrial & Engineering Chemistry*, July, 1929, pages 703–704.

The solubility of the metals nickel, tin, 18% chromium-steel, aluminum, zinc and copper in terms of milligram loss per square decimeter surface at temperatures from 20 to 100° C. was determined for an exposure of 30 minutes. Aluminum and tin are both very inactive in milk up to about 70°. Chromium-steel was found to be the most satisfactory. In a very few instances microscopic rust spots could be detected on strips that had been poorly polished. MEH

Surface Tension of Gold, Zinc, Gold-Copper, Silver-Copper and Iron Alloys. (Die Oberflächenspannung geschmolzener Metalle und Legierungen. Die Oberflächenspannung von Gold, Zinc, Gold-Kupper, Silber-Kupper und Eisenlegierimgen.) W. Krause & F. Sauerwald, with supplementing tests by M. Michalke. *Zeitschrift für anorganische und allgemeine Chemie*, July 20, 1929, pages 353–371.

The tests are described in detail; they were made by the bubble-pressure method which was modified somewhat for the tests of zinc and alloys of iron with carbon, phosphorus and silicon. The high surface tension of the rare metals and their alloys as also that of the iron alloys is noticeable; the latter alloys also show a positive temperature coefficient. Some rare metals show a maximum of the surface tension depending on the temperature. Ha

PROPERTIES OF NON-FERROUS ALLOYS

Electric Conductivity, Corrosion and Possibilities of Heat Treatment of Cadmium Zinc Alloys. (Die elektrische Leitfähigkeit, die Korrosion and die Vergütbarkeit der Kadmium Zink Legierungen.) G. Grube and A. Burkhardt. *Zeitschrift für Metallkunde*, July, 1929, pages 231–234.

The paper opens with a brief review of previous investigations on the constitutional diagram Cd-Zn. The experiments measured the electric conductivity of Cd-Zn alloys from room temperature up to the beginning of melting and thus determined the limits of saturation of the solid solution in relation to temperature. The isotherms take a course characteristic for a system containing a eutectic and partial solubility in the solid state. Furthermore, corrosion by solutions of caustic soda on Cd-Zn alloys has been examined, proving that from 0 to 17.4 percent Zn, only low amounts of zinc are dissolved, but sudden increase takes place after the passing of this eutectic composition. After the solution of Zn, a layer of Cd at the surface stops further attack. Finally, the improvement of mechanical properties by means of artificial aging and age hardening has been examined, since the solid solubility curves on both sides of the diagram show a decrease of solubility with falling temperatures. An alloy of 2 percent Cd was melted, rolled into sheets and small test pieces were cut out. Pure zinc was submitted to the same treatment. At room temperatures an increase of tensile strength from 20,300 lbs./in.^{2} to 27,000 lbs./in.^{2} and of elongation from 5.7 to 11.5% could be secured after 8 weeks. Similar tests at an aging temperature of 70° C. gave an increase of elongation from 6.0% to 14.5%. Hardness in both experiments was improved by about 20% of the initial values. All checked data are presented in tables and diagrams, showing the typical shape of improved curves with a quick rise of hardness and tensile strength immediately after quenching and a bend parallel to the abscissae after longer annealing times. EF

Contribution to the Knowledge of Tin-Bronzes. (Zur Kenntnis der Zinnbronzen.) N. Hansen. *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 25–29.

This investigation attempts to explain certain phenomena in the structure by a transformation at 587° C. Ha

Electric Conductivity of Silver Alloys. (Elektrische Leitfähigkeit von Silberlegierungen). M. Hansen & G. Sachs. *Mitteilungen der deutschen Materialprüfungsanstalten*, Sonderheft V, 1929, pages 152–154.

Test results on conductivity and hardness of silver alloyed with Cd, Mg, Zn, Mn, Al, Sn, Sb are given; the resistance increased in the order named. Ha

Velocity of Solution of Alloys in Hydro-Chloric Acid. (Ueber die Lösungsgeschwindigkeit der Legierungen in Slazsäure.) P. Fischer. *Zeitschrift für Elektrochemie und angewandte physikalische Chemie*, Aug., 1929, pages 502–505.

While pure zinc is not soluble in diluted acids impure zinc possesses a noticeable velocity of solution. This velocity was determined for alloys of Zn with Pt, Ag, As, Pb and Hg in 0.5 and 1.0 normal. The explanation is found in the theory of the local elements. Ha

Aldrey. Dr. A. Fuchs. *Siemens Zeitschrift*, March, 1929, pages 153–157.

Anticipating results of previous experiences, concerning the replacement of copper in high tension over-head lines by pure Al and steel-aluminum cables, the results obtained with the new Al-alloy Aldrey, after four years' use in Switzerland, are given: Tensile strength: 31.5-35 kg./mm.^{2}, electric conductivity: 30-32 m./ohms and mm.^{2} at 20° C., spec. grav. 2.7, modulus of elasticity; 6000 kg./mm.^{2} and coefficient of heat expansion: 0.000023. Economical considerations are discussed. EF

Appearance of Maximum Strength in Un-Aged Duralumin. (Auftreten von Festigkeitsvollwerten bei nicht gealtertem Duralumin. Zur Theorie der Duraluminvergütung.) P. Schwebe. *Metallwirtschaft*, August 9, 1929, pages 772–774.

The author reports on some investigations concerning the phenomenon that duralumin which has previously been treated once or several times attains its full values of strength after quenching in boiling water within 5 or 10 min. Reversibility and complete coincidence after two heat-treatments do not necessarily exist. The medium of quenching or the temperature interval during quenching is of a more essential influence upon the time of aging than it was assumed up to the present. But no cutting down of the time necessary for aging is reached on account of this phenomenon since a double treatment is needed. EF

Investigations on Lead Magnesium Alloys. (Untersuchungen an Blei-Magnesium Legierungen.) Ch. L. Ackermann. *Metallwirtschaft*, July 19, 1929, pages 701–702.

The author reviewed previous investigations (references given) concerning the influence of Mg upon Pb in bearing metals and added some other metals: Al, Zn, Tl, Sn, Ni, Cu in small amounts. Results: the physical properties of hypo-eutectic PbMg alloys (mostly of two percent Mg) are not practically influenced by additions of other components and resemble the low tin alloys of the pure ternary system Pb–Sn–Sb. Testing for friction stress under semi-liquid friction, the wear of an examined Mg alloy with an addition of Zn proved to be larger, it is true, but exhibited more favorable friction temperatures at longer running periods than the railroad standard metal used before. All Pb-alloys containing Sn, possess high strain of transcrystallization and burst along the crystal boundary surfaces after longer storage. Summarizing: the investigated alloys do not offer any advantage in comparison with the low tin Pb bearing metals of the Pb-Sn-Sb series which are cheaper and easier to machine. The publication includes two tables containing the composition of the alloys and the investigated physical properties as hardness, 2 percent compression limit, tenacity, friction stress, wear, temperatures, etc. A photomicrograph discloses in contradiction to the recognized principle of hard bearing crystals in a soft eutectic matrix, uniformly distributed, poorly developed segregations of $MgZn_2$ beside a hardened matrix of $Mg_2Pb + Pb$. EF

PROPERTIES OF FERROUS ALLOYS

Classification of Gray Iron Alloys. J. W. BOLTON. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 9 pages.

On the basis of carbon content, classification in groups with carbon from 2.50% to 3.50% by 0.25% steps, plus one group above 3.50, with eight subgroups of silicon in 0.25% steps, from 0.75% to 2.50% and up, is suggested as a basis for chemical classification. On the basis of carbon plus 0.3 × the silicon, or carbon plus silicon, these 40 groups reduce to less than 20. Five phosphorous sub-sub-classifications are suggested, so there are 200 suggested classes on one basis and 100 on the other, without considering manganese, sulphur or any of the alloying elements like nickel and chromium. Then each chemical class has to be considered on the basis of surface to volume. Bolton uses 33 steps with a volume: surface ratio varying from 0.12 to 1.6. Hence there would be a possible total of 40 × 33 or 6600 classes when carbon, silicon, phosphorous and size and shape of casting are all considered. Many other variables are mentioned, bringing out the fact that "gray iron" is the name, not for a single alloy, but for a huge series of alloys, so large that some classification is essential for logical study. HWG

Effect of Section and Various Compositions on Physical Properties of Cast Iron. R. S. MACPHERRAN. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 7 pages.

The strength, hardness and structure from center to surface of bars ranging from $1\frac{1}{4}$ to 4″ diam. were studied for 3 irons, a hard, low silicon iron; a soft, high silicon iron; and a nickel-alloyed, high-test cast iron. Hardness data plotted against distance from the surface, and tensile strengths from center and edge of bar show that the high-test iron is more uniform in hardness throughout than are the other two irons, and that the center of the 4″ high-test bar is stronger than the outside of the $1\frac{1}{4}$″ bar or even the harder of the other two. HWG

Correlation of Cast Iron Test Bars and Castings. W. H. ROTHER AND V. M. MAZURIE. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 5 pages.

Agrees with Bolton that cast iron is a series of alloys, and with MacPherran on effect of change of section. Suggests that future specifications will call for test bars of several sizes. HWG

Static Strength of Plain and Alloy Cast Iron. F. B. COYLE. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 7 pages.

Maurer type diagrams showing effect of composition including nickel and chromium, on strength and structure of cast iron. HWG

Elastic Properties of Cast Iron. J. T. MACKENZIE. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 5 pages.

If applied under clearly defined conditions, the modulus of elasticity is a useful indication of the quality of cast iron. Plastic deformation of cast iron is closely related to the amount of graphite. The "ultimate" modulus (that after 6 loadings of a transverse bar to $\frac{3}{4}$ the ultimate strength) is a good index of resistance to plastic deformation. HWG

Carbon Steels of Low Aging Quality. (Flussstähle mit geringer Alterungseigenschaft.) *Mitteilungen der deutschen Materialprüfungsanstalten,* Sonderheft V, 1929, pages 12–22.

Paper read before the Convention in Duesseldorf. The properties of a material which stand the high requirements for boiler plates for very high pressures are thoroughly discussed and illustrated by micrographs and stress-diagrams. HA

The Fatigue Properties of Cast Iron. J. B. KOMMERS. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 9 pages.

Summary of fatigue tests previously reported by Kommers and by H. F. Moore. Notches reduce the fatigue strength of cast iron less than that of other ferrous materials. The endurance limit ranges from 33 to 57% of the tensile strength, in various irons. HWG

CORROSION, EROSION AND PROTECTION OF METALS AND ALLOYS

Corrosion of Cast Iron. H. O. FORREST. Preprint No. 35, for publication in *Proceedings American Society for Testing Materials,* **29** (2), (1929), 10 pages.

Factors other than the metal itself, such as the nature of the corrodent and of any protective coat or film applied to the iron or formed by the corrodent are rather more important than variations in composition or structure of the iron. In tests at Massachusetts Institute of Technology still in progress, the average corrosion rate of twelve different (unalloyed) cast irons varies only ± 7%. Slight differences in pitting rate have still to be completely studied. High silicon iron (4% Si) or high nickel iron (up to 14%) have high resistance to corrosion, but ordinary cast irons act about alike and the varying lives met in service depend on the continuity of any protecting coat such as asphalt or cement and on the nature of the corrodent, i. e., whether it forms a protective coating or not. HWG

Salt Spray Testing Equipment. *Brass World,* July, 1929, page 173.

This apparatus consists of a square tank of white enameled steel, with Monel trimmings and glass top, mounted on legs. It is equipped with a sloping drain and glass rack, it is gas-tight and adapted to testing plating of various kinds. It is manufactured by the Belke Mfg. Co., Chicago, Ill. WHB

Electrolytic Corrosion Damages by Current Leakage and Stray Currents and Their Prevention. (Electrolytische Fress-Schäden durch Stromlecken und vagabundierende Ströme und deren Verhütung.) G. ANGEL AND CHR. BECK-FRIIS. *Chemiker Zeitung,* July 17, 1929, pages 553–554; July 24, 1929, pages 574–575.

In certain direct current plants troubles occur due to electrolytic corrosion produced by stray currents. Two remarkable examples: an electrolytic plant and a street railway are fully described and prevention outlined. Some formulae and equations for determination of the current losses are derived, by means of which in one case a loss of 2% of the input was determined. EF

On the Oxidation of Copper at High Temperature. (Ueber die Oxydiation des Kupfers bei hoher Temperatur.) F. J. WILKINS. *Zeitschrift für Elektrochemie und angewandte physikalische Chemie,* Aug., 1929, pages 500–501.

Conclusions on the relation between velocity of oxidation of copper and time at temperatures between 600 and 1020° C. which were based on tests by Feitknecht were shown not to be justified. Instead, by an exactly parabolic law the oxidation can be very exactly expressed by the equation $x^2 = kt + c$ where x is the increase in weight, t time and k and c constants. The results are discussed in detail. HA

General Principles in Observing Oxidation-Reduction-Reactions and the Question of the Substance of Chemical Affinity. (Allgemeine Prinzipien bei der Betrachtung von Oxydations-Reduktionsreaktionen und die Frage über das Wesen der Chemischen Bindung.) II, III. BR. JIRGENSONS. *Zeitschrift für Elektrochemie und angewandte physikalische Chemie,* Aug., 1929, pages 473–483.

In the first part of this work the author demonstrated that the usual definition of oxidation and reduction, respectively, as increase or diminution of the positive valency or as diminution and increase respectively of the negative valency, can be applied generally if it is assumed that all compounds are more or less of a polar nature. For explanation, the conception of oxidation-stage-number is introduced which is defined as the algebraical sum of the positive and negative valencies of the atoms taken with opposite sign. The meaning of this conception is thoroughly explained by several examples and it is shown that by means of these oxidation-stage-numbers the coefficients for the oxidation-reduction-reactions with inorganic, organic and complex compounds can easily be calculated. At the same time, the author discusses his theory and compares it with the octette theory. In the light of his theory, the mobility of the H-atoms in organic compounds and the dissociation phenomena are discussed. In the third part some consequences of the theory with regard to the oxidation stages of the individual atoms in a complex compound which can be reduced or oxidized, induced polarity and non-saturated compounds and substitution phenomena are treated. HA

STRUCTURE OF METALS AND ALLOYS

Metallography and Macrography

Effect of Rate of Cooling on the Microstructure of Steel. J. M. Robertson. *Fuels & Furnaces*, Aug., 1929, pages 1155–1159.

Abstract of paper presented before Iron and Steel Institute, May, 1929. Cf. Metals & Alloys, July, 1929, page 25. MS

A New Reagent for Macroscopic Metallography. (Un Nouveu Reactif de Metallographie Macroscopique.) Georges d'Huart. *Revue de Metallurgie*, June, 1929, pages 300–306.

A new reagent for macroscopic etching is described. Dissolve 16 gm. $NiCl_2$ in 200 cc. warm HCl (1:1) and *after cooling* add 40 gm. crystalline chromic acid. The reagent does not keep. Stock solutions keep well and are mixed before using. Recommended: (1) 16 gm. $NiCl_2$ in 100 cc. HCl (2:1); (2) 49 gm. chromic acid in 50 cc. water; the reagent does not deposit any metallic layer and specimens can be photographed directly after etching, preferably submerged in a shallow bath of water acidulated with $ZnCl_2$. The etching takes place from a few seconds to a minute. Prepare the specimen as for sulphur printing, immerse in solution and agitate during etching. It is particularly suitable for soft steels, irons and copper with its alloys. Develops well: macrostructure, fissures, segregations (especially of P and S) and flow lines. For the latter, better results are obtained with: 100 cc. H_2O, 140 HCl, 40 gm. Cr_2O_3, 16 $NiCl_2$, 8 $CuCl_2$. The formation of copper deposit during washing is prevented by first washing in diluted HCl. Photographs are given comparing the results produced by the reagent with specimen etched with Heyn, Le-Chatelier and Oberhoffer solutions. JDG

Standard Grain Size Micrographs. Appendix to the report of the Committee on Metallography of the American Society for Testing Materials, presented at the June, 1929, meeting and to be published in Vol. **29** (1) of the Proceedings of the Society.

Contains 12 micrographs of 70:30 Cu-Zn brass showing grain sizes, at 75 diameters averaging, on the basis of observations by half a dozen qualified metallographers, as follows, in millimeters: 0.010, 0.016, 0.024, 0.003, 0.045, 0.067, 0.090, 0.122, 0.147, 0.197. Comparison of these with micrographs, or with the visually observed fields, of specimens whose grain size is desired, will allow close approximation of grain size without tedious measurement. Every metallographer will find the series of standards useful. The report may be purchased from the Secretary of the A. S. T. M. at 1315 South Pierce Street, Philadelphia. HWG

Structure and X-Ray Analysis

Analyses of Metals by Electron Waves (Metallanalyse mit Elektronenwellen). E. Rupp. *A. E. G. Mitteilungen*, Aug., 1929, pages 535–540; *Metallwirtschaft*, May 10, 1929, pages 446–448.

The theoretical fundamentals of the latest conception concerning the nature of electron rays are given alongside the modern theory on the nature of light (Einstein, de Broglin, Schroedinger). Electrons are considered to possess wave properties besides their corpuscular nature. The derivations and the final equation of de Broglin are reproduced showing that an electron ray of 150 volts corresponds to a wave-length of 1×10^{-8} cm., which belongs to the order of magnitude of ordinary X-rays. There are seven different methods to prove the wave nature of electrons. In the present paper stress has been laid upon the investigations of surface structures by electron waves. The tube used in experiments along those lines is illustrated and the operation described. A unique way of producing proper crystals with fibrous structure is given. Some results from three experiments with Au, Ag, and Cu are presented graphically and in tabular form. Two practical applications: the localization of gas atoms in single crystals of nickel and the placement of thorium in tungsten filament promote further investigations. EF

The Crystal Structure of Barium. A. J. King and G. L. Clark. *Journal American Chemical Society*, June, 1929, pages 1709–1711.

The crystal structure of very pure barium has been found to be body-centered with a parameter of 5.015 ± 0.003 Å. The atomic radius calculated from the data is 2.171 Å. at room temperature. MEH

PHYSICAL, MECHANICAL AND MAGNETIC TESTING

Elongation of Sheets. (Die Dehung von Blechen.) G. Sachs & W. Stenzel. *Metallwirtschaft*, June 7, 1929, pages 547–556.

Testing of thin sheets by tensile tests are much applied. There are tendencies in Germany and the U. S. A. to standardize these tests. Difficulties arise from the measurement of the deformed external dimensions as for instance the reduction of area. Only the ultimate elongation is of practical importance since easily determinable. But dimensions of test pieces as well as method of measurements should be standardized. References of 7 previous publications are anticipated and their results discussed. In the present investigation a study has been made concerning the relations between ultimate elongation and the ratio of width: thickness. The tested material was bronze (DIN 1705 Sheet 1 WB_26 which contains 6–10% Sn) in form of test rods for sheets with 5.0, 2.0 and 0.5 mm. thickness. The experimental results are clearly arranged in two tables and demonstrated by 14 diagrams. The test pieces had no geometrical similarities so that the ratio $l:d$ and $b:a$ continually varied. (a = thickness, b = width, l = length, d = diameter.) By means of two diagrams a comparison is possible with test pieces of other external dimensions as used in foreign countries. EF

Electro-Magnetic Testing of Wire Ropes. *Iron and Coal Trades Review*, July 19, 1929, page 81.

Discussion, and author's reply, of the Paper by T. F. Wall (cf. *Ibid.*, June 14, 1929, pages 907–908). The apparatus described would detect results of such changes as broken wires or corrosion, but not detect a wire which was mechanically continuous but brittle. One colliery has a testing equipment in use with a proper frequency changer. It requires about 10 minutes to put the rope-tester in position and the same amount of time to dismantle it. A test might be made once a month until the rope becomes suspect, when a special test could be made more often. WHB

Notch Effect in Industry and Science. (Kerbwirkung in Technik und Wissenschaft.) E. Seidle. *Mitteilungen der deutschen Material Prüfungsanstalten*, Sonderheft V, 1929, pages 122–130.

After a definition of "notch" the effect of a notch on the physical properties of a material are discussed and also how they can be obviated. The notch effects a concentration of stresses at its base, which, if not properly taken care of, give rise to dangerous stresses in the finished material. A great number of microphotographs of structures taken in several consecutive stages of rolling and forging processes illustrate the paper. Ha

Tensile Tests on Crystals of Copper and Brass. (Zugversuche an Kristallen aus Kupper und Messing.) V. Goeler & G. Sachs. *Zeitschrift für Physik*, June 27, 1929, pages 581–620.

The deformation phenomena taking place in tensile tests which have been investigated and fully recognized in pure metals show entirely different in solid solutions, at least of copper. The present investigation determines experimentally the changes and the geometrical and tensile conditions in their relation to the contents of zinc. The lattice constants, as a function of the amount of zinc present, are tabulated in an appendix; numerous curves and photographs and also bibliographic references are given. Ha

Tension, Bend and Impact Tests on Reinforcement Bars. W. A. Slater and G. A. Smith. Preprint No. 91, for publication in *Proceedings American Society for Testing Materials*, **29** (2), (1929), 21 pages.

Reinforcement bars bought on the open market were tested to see whether bending a bar, as is done to give it anchorage in concrete, injured its strength. The strength was found to be but slightly affected. A special impact machine designed to stress bars of different sizes equally under the impact failed to show brittleness in any of the commercial specimens tested, but did show brittleness in water quenched specimens. A special bend test machine, also designed to produce equal stresses in all sizes of bars when bent through the same angle was employed. A few of the harder bars broke in the bend test. Square bars failed in bending to a much greater extent than round ones. The different lots of bars tested varied widely in tensile strength, but the analysis of the bars is not given. HWG

ELECTRO-CHEMISTRY

Electroplating

Cadmium Plating. (Sur le Cadmiumage.) GUILIANO MONTELUCCI. *Revue de Metallurgie*, June, 1929, page 340.

The author points out that he has shown that in addition to the electrolytic method of cadmium-plating the application of a eutectic zinc-cadmium alloy at the melting temperature has given equally satisfactory results. HA

Tilted Plating Barrel. *Brass World*, July, 1929, page 172.

The "Bull's Eye" plating barrel is manufactured by Lasalco Inc., St. Louis, Mo. Novel features include: the center negative conductor, and plating of the load without plating the inside of the barrel. Inside dimensions of the barrel are: 21 inches at the top, 24 inches at the bottom and 21 inches in depth. WHB

Further Observations on the Shape of Electrolytically Deposited Metals. (Weitere Beobachtungen über die Form elektrolytisch abgeschiedener Metalle.) F. FOERSTER AND K. KLEMM. *Zeitschrift für Elektrochemie und angewandte physikalische Chemie*, July, 1929, pages 409–426.

The authors examine more closely the peculiar phenomenon of a metallic precipitation of tin from stanno-salt solutions. According to the crystalline structure the deposited, material takes the same form as that of the electrode, and if the latter has not an outspoken structure, as, i. e., in rolled material, the deposit becomes finely crystalline. Zinc and lead behave similarly. By adding certain acidic solutions to the electrolite the crystal growth of the deposits can be influenced in a definite direction. Tests are given in detail for deposits of Cd, Zn, Th and Pb. HA

Is Superposed Alternating Current Worth While in the Plating Room? *Brass World*, July, 1929, pages 164–6.

A review of a paper by H. C. Cocks on "Some Possible Uses of Alternating Currents in Electrodeposition." The paper was read before the Electroplaters' & Depositors' Technical Society in London. The only case of the technical use of superposed a. c. in electrolysis is that of the Wohwill modified gold-refining process. At present disadvantages outnumber the advantages for the use of the process in commercial electrodeposition. WHB

Electrometallurgy

Electric Brass Melting. J. B. MEIER. *Electrical World*, August 17, 1929, pages 313–316.

A practical man's observation of the melting of more than 2,000,000 pounds of brass in electric arc furnaces is that there are lower melting costs, decreased metal losses and better working conditions where electric heat is used. The layout of furnaces and molding floor at the plant of the F. & H. Foundry Co., Newark, N. J., is shown in diagram. WHB

A Cylindrical Tilting Reverberatory Furnace for Melting Aluminum Alloys. (Ein zylindrischer Kippflammofen zum Schmelzen von Aluminum Legierungen.) R. J. ANDERSON. *Metallwirtschaft*, August 2, 1929, pages 747–748.

The furnaces generally used in the foundry for melting Al alloys are briefly reviewed and the author's new drum furnace heated by gas or oil is described and explained by means of several sketches and photographs. The present capacity of 2700 kg. could be increased to 10,000 kg. according to the opinion of the author, who besides this claims a more efficient heat utilization in the furnace and lower initial costs. The lining is expected to withstand two years' operation. EF

Electric High Temperature Furnaces. (Elektrische Hochtemperatureöfen.) E. LOWENSTEIN. *Metallwirtschaft*, May 3, 1929, pages 425–427.

A melting furnace according to Nernst-Tammann, containing a carbon tube as resistance, is described and illustrations are presented. A set of curves, in which input in Kilowatts is plotted against temperatures and the required energy in Kilowatt-hours for the melting of 14 different metals are given. In contrast with induction and high frequency furnaces, non-metallic materials as silicates, refractories, ores, etc., can be heated up to 2500° C. and above. EF

METALLIC COATINGS OTHER THAN ELECTROPLATING

A Comparison between Metal Coating Processes. JAMES SILBERSTEIN. *Brass World*, July, 1929, pages 170–171.

A brief outline of: (1) hot dipping, (2) electroplating, (3) diffusion (sherardizing) and (4) metal spraying. There is shown to be a special sphere of application for which each is particularly suitable but also distinct limits to the exploitation of each. WHB

Electric Galvanizing Tank Cuts Cost One-Half. *Electric World*, August 24, 1929, page 373.

At the Alhambra shops of the Southern California Edison Co., a tank 3 ft. × 5 ft. × 3 ft. inside measurement is equipped with 70 kw. in 3-phase 220 v. G. E. heaters. A Brown recording pyrometer furnishes temperature-control. Steel cross arm braces are galvanized with a 45-second immersion at a cost of 14.4 per lb. of work galvanized, compared with 27.5¢ with a gas-fired tank. Dross savings are $120 per month. Working conditions are better and automatic temperature control permits the operator to give his entire time to immersion of the work. WHB

The Galvanic Zinc Coating of Wires. (Die Galvanische Drahtverzinkung.) K. SCHUCH. *Chemiker Zeitung*, May 22, 1929, pages 397–398.

The process of galvanic coating of wires with zinc, which is cheaper and results in a greater corrosion resistance than wires coated by molten zinc, is described and the most interesting data are given, some of which may be reproduced here: 5 volts, 5–15 amp./dm.^{2}, bath: 100 liters water, 32 kg. zinc sulphate, 9 kg. ammonium sulphate, 5 kg. sodium sulphate, 3.5 kg. boric acid; temperature of bath: 45–50° C., kind and amount of colloidal additions are given, zinc consumption: 50–70 g./m.^{2}, monthly output in case of 50–60 wires coated at the same time each 1.5–4 mm. thick: 700 tons. EF

INDUSTRIAL USES AND APPLICATIONS

The Use of Hard Metals in Germany. (Die Verwendung der Hartmetalle in Deutschland.) G. SCHLESINGER. *Werkstattstechnik*, July 1, 1929, pages 381–387.

The development of cutting tools, grouped in the following manner is given: high speed tool steels, cast hard metals and sintered hard metals. Cutting tests with the last mentioned groups show that sintered hard metals (tungsten carbide) are best suited for cutting at high speeds. The shape of the tool is of great importance and varies much according to the purpose. High speed machine tools should be built to take advantage of the properties. GN

Question of Material in Propeller Construction. (Die Frage des Werkstoffs fur Luftschrauben.) F. SEEWALD. *Zeitschrift für Metallkunde*, July, 1929, pages 227–230.

Two materials for the construction of propellers are discussed and compared with respect to technical demands in airplane service substantially characterized by the increase of units and, to a smaller extent, of rotations without the necessary enlargement of the diameter of the propeller. Thus, efficiency is decreasing and centrifugal forces approach dangerous limits. Mechanical destruction by rain, sand, sea-water-spray, etc., show up in case of wood. The second difficulty arises from the relative thickness of propellers, which only work with a satisfactory degree of efficiency at speeds far below the velocity of sound. The decrease of efficiency can be successfully met by the application of thin, sharp-edged profiles. Furthermore, insensitivity against weather influences must be considered. The static and vibration stresses are detailed and necessary qualities and properties are derived from them. Several representative propellers as the Reed, Ruppel, Haw and the Standard Steel Corporation's (solid light metal) propellers are described. The author is inclined to believe that hollow propellers have a greater promise for future development characterized by an increase of diameter of propellers and reduction of rotations. EF

Copper, Brass and Bronze in Modern Ship Building. W. C. WOLFE. *American Zinc, Lead and Copper Journal*, May, 1929, page 4.

Applications of non-ferrous metals and alloys in the new Canadian "Duchess" class. EF

HEAT TREATMENT

Fundamentals Underlying the Heat Treatment of Steel. O. W. Ellis. *Canadian Chemistry and Metallurgy*, July, 1929, pages 23-28.

The fundamentals for proper heat treatment of steel are: furnace atmosphere, temperature distribution, correct temperatures, structural changes, the critical point, the effect of various temperatures and cooling rates. Each subject is briefly reviewed and several tables and diagrams are given. WHB

Annealing

Crystalline Changes in Copper Due to Annealing. F. C. Howard & E. T. Dunn. *Industrial & Engineering Chemistry*, June, 1929, pages 550–553.

Etching with concentrated nitric acid brings out the grain boundaries, twinning, etching pits and fine grain structure. With ammonia and hydrogen peroxide, twinning and etching pits, and in some cases grain boundaries are observed, but not the same type of fine structure as when etched with nitric acid. Photomicrographs show how grain growth continues with repeated heating. Laminations were still visible after 80 hours of heat treatment at 700°. CMEH

Heat Treatment of Cast Iron. F. B. Coyle. Preprint No. 35, for publication in *Proceedings, American Society for Testing Materials*, 29 (2), (1929), 4 pages.

Brief discussion of the possibilities in heat treatment of cast iron for relief of stresses, softening for machining and control of physical properties. No experimental data. HWG

Case Hardening

Differential Method for Measuring the Thickness of Hard Cases without Sectioning Them. Edward G. Herbert & Paul Whitaker. *Iron and Coal Trades Review*, July 5, 1929, pages 8–9.

An abstract. A reading of the hardness test is influenced by three variables, i. e., the hardness and the thickness of the case, and the hardness of the core, but fails to discriminate or to determine any one of them. The method described consists of making two different hardness tests, a primary—measuring only one variable, the hardness of the case; and a second test measuring the combined effect of two variables, hardness and thickness of case. The difference between these readings is a function of the second variable, thickness of case. The third variable, hardness of core may be treated as a constant for any given variety of steel. The two hardness tests are the pendulum time test and the Brinell test. The cloudburst test consists of the dropping of a very large quantity of hard-steel balls from a known height which is so chosen that steel of correct hardness is unmarked by the impact of the balls, but any areas of inferior hardness are indented. This test detects thin spots, as well as soft spots. It is proposed to apply the differential method to the measurement of thickness of cases in nitrated steels, and to the thickness of chromium plate. A brief discussion follows. WHB

Aging

Improvement of Alloys. (Von der Veredlung der Metallegierungen.) W. Guertler. *Metallwirtschaft*, May 24, 1929, pages 510-515.

The contradictory terminology of "improvement" is critically discussed. The metallographic hypotheses for an improving treatment are fully explained by means of the diagrams Fe-C and Al-Cu. The practical carrying out of an improvement in the case of duralumin is given. The theoretical basis for further possible improvements are outlined showing the importance of knowledge and application of constitutional diagrams. EF

Pyrometers and Controllers

Tellurium Thermo-Couples. (Tellur-Thermoelemente.) B. Lange and W. Heller. *Physikalische Zeitschrift*, July 1, 1929, pages 419–425.

The authors describe a copper-tellurium and a platinum tellurium thermo-couple and the tests to determine the constancy of the thermo-electric force. The latter is about 400×10^{-6} volt or 0.4 millivolt per 1° C. over a temperature range from 0 to 400° C. Ha

JOINING METALS AND ALLOYS

Welding and Cutting

Arc Welding in the Brainerd Shops of the Northern Pacific Railway Company. G. H. Gjertsen. *General Electric Review*, August, 1929, pages 420–423.

The oval-shaped wheel centers were built up by mounting them in a special lathe or depositing metal on their peripheries by the arc-welding process until they were again round, then machining them to their original diameters in a lathe, permitting the remounting of tires that had been removed from that pair of wheels or to use the other tires of standard bore. The set up is illustrated. The welding process has proved economical and satisfactory. In the last three years the Company has built up 1369 pairs of locomotive driving wheel centers, 88 pairs of trailer-wheel centers and 1392 guides in the shops at Brainerd, Minn., South Tacoma Wash. and Livingston, Mont. WHB

WORKING OF METALS AND ALLOYS

Progress in Iron and Steel Manufacture in Germany. *Iron and Coal Trades Review*, July 5, 1929, page 5.

An abstract of an article appearing recently in *Stahl und Eisen* written by O. Petersen. Progress is indicated toward the direct production of steel. Grinding of iron ores is becoming more general. Blast furnace dust has been used by blowing it into the stack by compressed blast furnace gas. WHB

The Computation of Power Requirements in Forming and Shaping Processes. (Die Erfassung des Arbeitsbedarfs bei technologischen Formgebungsprozessen.) E. Siebel. *Metallwirtschaft*, July 26, 1929, pages 724–726.

The necessity for knowledge on the energy required in forming processes is recognized. Two ways of computing the necessary work are outlined, which may be considered as an analytical and synthetic method. Difficulties in the latter case arise from the determination of the pure work necessary for plastic deformation without loss. But the theory of shearing stress, which is briefly explained, has become an applicable hypothesis for actual working conditions. The author states the theoretical work A_t in case of forming processes by pressure without loss: $A_t = V_d.k_f = V.k_f. \ln\phi$ in which equation V_d = displacement of volume along the main direction of deformation, k_f = average resistance to deformation. V_d represents the product of volume V of the deformed body and the deformation $\ln\phi$ is computed as the natural logarithm of the ratio of the external dimensions before and after deformation along the main direction of deformation. It is explained how to obtain the value of the resistance to deformation in both cold and hot working, but losses occur due to friction and internal shifting. While the losses caused by friction can be estimated or calculated, there are some difficulties for the second value. But the theoretical and actual work for deformation, and thus the efficiency, can be determined. The similar formulae for extruding are derived and explained. Some influencing factors as shape of dies, reductions in cross sections, etc., are mentioned. The author's experiments on drawing of wires and tubes are graphically presented: deformation is plotted against efficiency of deformation process in percent. The actual values can be determined by means of equations given above and a diagram. Two practical examples from checking rolling mills are described, each of which resulted in an improvement of the plant factor. EF

A Melting Record of Three Acid Open Hearth Heats. W. E. Griffiths & C. E. Meissner. *Transactions American Society for Steel Treating*, August, 1929, pages 257–292.

Paper presented before the tenth annual meeting of the Society in Philadelphia, October 8 to 12, 1928. Includes discussion. The complete logs of three acid open hearth heats as made in a 25-ton open hearth furnace are presented. The records show the effect of adding silicon in the ladle rather than in the furnace. The effect of the various alloys, additions on the slag composition and metal bath analysis is depicted graphically. A discussion of the curves of composition of bath plotted against composition of slag, and carbon manganese, silicon content against time, is included. ESC

Casting

Heterogeneity of Steel Ingots. Part IV. Mathematical Consideration of the Effect of Latent Heat on the Solidification of Steel Ingots. *Rolling Mill Journal*, Aug., 1929, pages 349–350.

Abstract of a paper by N. M. Lightfoot, constituting the final section of the third report of the Committee on Heterogeneity of Steel Ingots of the Iron and Steel Institute. Considers three hypothetical cases, which give an idea of the progress of the rate of freezing at the outer wall and of the conditions that apply toward the latter stages of freezing at the center of the ingot. MS

Machining

Tungsten Carbide as a Cutting Tool Material. H. J. Long and W. P. Eddy. *Mechanical Engineering*, August, 1929, pages 596–597. Paper before A. S. M. E. Research Committee 13–15, May, 1929, Rochester, N. Y.

The authors give some experiences in design, and fabrication and application of tungsten carbide tools, which must be very different depending upon their application. Some samples of successful and unsuccessful applications are given, showing that in the right place production can be increased by many hundred percent over that in turning with high speed steels. Malleable cast iron, gray cast iron, alloy steels, bronze, bakelite could be machined very successfully. The application in automatic screw machines on the other hand is of no use. Modification of machine tools is necessary. GN

Pickling

Pickling Steel for Vitreous Enameling. F. G. Jaeger. *Metal Cleaning and Finishing*, July, 1929, pages 299–302.

For most efficient pickling action, strength should be 2–4% for H_2SO_4 and about 3–5% for HCl. Where heavy scale is encountered it may be necessary to use an acid content of 10%. High acid concentrations are objectionable as they tend to cause blisters. Use of niter-cake is growing in importance as it makes possible a saving in cost of pickling and absence of acid burning and etching. Agitation and heating of the bath are essential conditions for efficient pickling. Mechanical agitation is to be preferred to steam agitation. Organic materials, such as sugars, flours, etc., sprinkled over the surface of the bath, are used to eliminate fumes. MS

Cold Working

The Cold Working of Steel. Research Laboratory for Sheffield University. *Iron and Coal Trades Review*, July 19, 1929, page 80.

This new laboratory will undertake problems in drawing, rolling and pressing. A complete X-ray outfit is one of a well-rounded stock of appliances available. WHB

Change of Hardness and Structure of Cold-Worked Hoop Steel with Carbon Contents of 1.15%, 0.90% and 0.60% by Annealing. (Hårdhets och strukturförändringar vid glödging av kallvalsät stäl av kolhalterna 1.15; 0.90 och 0.60%.) R. Jonson. *Jernkontorets Annaler*, May, 1929, pages 207–235.

The influence of annealing after cold working is examined with hoop steel, containing 0.60, 0.90 and 1.15% carbon. The results verify the German and American papers on this subject. A great number of etched samples are shown and references given. GN

PLANTS AND LABORATORIES

Heat Treating in Making Springs. F. W. Manker. *Iron Age*, July 25, 1929, pages 218–220.

Describes method employed by the Kokoma Spring Co. The importance of controlling the physical properties of steel wire for compression and tension springs. The heat treating furnaces are gas fixed and are used interchangeably for hardening and drawing. One drawing furnace is of the drum type. Two furnaces are used for tempering or blueing and japan baking. There are also two portable forging furnaces which may be moved from one punch press to another. Oil is the principal quenching medium. Chrome-vanadium steel, S. A. E. specification 6150 is heat treated at a temperature of from 1500 to 1525° F. and soaked from 10 to 20 minutes. After quenching, it is drawn at 800 to 100° F. To relieve any remaining strain it is reheated to 650° F. for one hour. Steels for compression springs, S. A. E. specification 1020, are heated from 1425 to 1500° F. for a half-hour, quenched and drawn at 900 to 1100° F. for from twenty minutes to two hours. VSP

DEFECTS

A Study of Burning and Overheating of Steel. Part I. W. E. Jominy. *Transactions of the American Society for Steel Treating*, August, 1929, pages 298–313.

Steel which is being heated for forging may become overheated resulting in "burning." It is shown that no chemical reaction of oxygen with the steel is necessary for this to occur. "Burning" is manifested by the appearance of voids around the crystal boundaries of the metal. Steels of less than 0.55% carbon in a reducing atmosphere seem to be protected from burning. This is not true of hypereutectoid steels. A strongly oxidizing furnace atmosphere causes these lower carbon steels to burn at relatively low temperatures. Under such conditions plain carbon steels actually become hotter than the furnace atmosphere in which they are heated. "Burning" is shown to occur in vacuum. ESC

Recent Development in Boiler-Metal Embrittlement. H. F. Rech. *Mechanical Engineering*, August, 1929, pages 589–593.

The investigation of some failures in boilers which occurred in different places and under most varied conditions seem to show that the theory of hydrogen embrittlement cannot be maintained. Boiler cracks, originating from embrittlement, occur only with materials overstressed, that is to say, over the yield point. The cracks were ever found intercrystalline. The theory up to the present is the best to explain the observed failures in most cases. GN

Trouble Shooting with Microscopes. E. K. Smith and F. B. Riggan. *Iron Age*, July 18, 1929, pages 145–147.

Attempts to give illustrative examples in the use of the microscope for the location, investigation and prevention of many common troubles often arising in the foundry. VSP

CHEMICAL ANALYSIS

Method for the Estimation of Hydrogen in Steel. T. E. Rooney and Guy Barr. *Iron and Coal Trades Review*, July 12, 1929, page 41.

From a Paper read in London before the Annual Meeting of the Iron & Steel Institute. Samples of steel were heated in a known volume of nitrogen and the volume of hydrogen evolved was measured by means of the Shakespeare katharometer. The laboratory type of katharometer in which two spirals of platinum wire are mounted in separate cells in a metal block, was used. Small brass tubes communicated with each cell and one was connected to the app. as indicated in Figure 1. The other was connected to the pure nitrogen supply. The two spirals formed two arms of a Wheatstone bridge, which is completed by two manganin resistances. A constant working current of 0.12 amp. was used and a deflection type of galvanometer giving zero deflection with the same gas in both cells was employed in the bridge. The apparatus, its calibration and means of determining hydrogen by measuring the volume of hydrogen evolved are described. The method has been employed successfully in the case of several samples of mild steel, which have been subjected to special conditions. When necessary, analysis is made of the gas by ordinary gas analysis methods. It is possible to detect 0.05 cc. of hydrogen. At 600° C. all the hydrogen is evolved in 1 hr. Higher temperatures tended to decompose the small amount of hydrocarbon gas present. WHB

HISTORICAL AND BIOGRAPHICAL

Historical Survey of Flotation. (Historique de flottage.) Ch. Berthelot. *Revue de Metallurgie*, July, 1929, pages 364–366.

A brief historical survey of the flotation processes. JDG

The History of Polishing Gold. (Zur Geschichte des Poliergoldes.) F. Chemnitus & P. Narr. *Chemiker Zeitung*, July 24, 1929, pages 573–574; July 31, 1929, pages 590–591.

A historical review beginning with purple of Cassius in 1683 up to the present time is given including the recipes. EF

MACHINERY AND SUPPLIES

Electric Furnaces in the Work-Shop. (Elektrische Widerstandsöfen im Werkstättenbetrieb.) H. Tamele. *Siemens Zeitschrift*, February, 1929, pages 101–108.

Advantages and economy of electric furnaces in general. (1) Furnaces with Cr-Ni winding including muffle-furnaces and salt-bath crucible furnaces. Industrial applications: (2) Hardening furnaces for high speed steels; (3) Melting furnaces. EF

Translations

Negotiations are now under way which will assure the appearance of translations of articles appearing in foreign publications. Under this arrangement, the readers of METALS & ALLOYS *will be assured of receiving in English the best articles at almost the same time as they appear abroad instead of three months to one year later.*

The Corrosion of Brass

By Max Haas, Aachen

(*Translated from Korrosion und Metallschutz, Feb., 1929, pages 25–35.*)

Investigations and literature on corrosion of brass have increased so greatly during the last decade that a concentrated review becomes an imperative necessity. On doing this in a critical manner it becomes evident that most of these published investigations represent unsystematic occasional investigations, carried out on account of an accidental need in practice. In isolated cases in the literature, classic works performed on a systematic basis are found, as, for instance, the works of Lasche in Germany, those of Bengough and the Corrosion Committee of the Institute of Metals in England, and those of Basset and his collaborators in America. In addition to these there are the fundamental, merely scientific publications on the nature and the mechanism of corrosion, as, for instance, those of Tammann and his students in Germany and of Ulick Evans in England. During the attempt of evaluating objectively the different results by means of large-scale investigations, other very important conclusions frequently resulted which usefully homogenize for science and practice the scattered publications in their apparent dispersing tendency. Herewith, it is to be regretted that an error of many writers is that they accept the publications of other investigators from some reports in periodicals without criticism, instead of examining the originals. This condition accounts for much over- and under-valuation.

In the originals one usually misses a clear diagnosis of preparatory treatment of the material, so that the attempt of arranging the earlier publications in a comprehensive table according to certain viewpoints will be a failure.

The varieties of the causes of corrosion on brass, as well as the numerous alloying and commercial types, naturally complicate the problem. This fact certainly explains the reason boundless discussions usually start with rules on metallographic etching methods, then touch the popular condenser problems and end with the traditional drawing marks.

It would be a task, much appreciated, for the Reichsausschuss für Metallschutz to publish as soon as possible a clear, brief, special pamphlet on corrosion and protection of brass, as a handbook for the industrial laboratories which usually have neither the time nor the opportunity to examine the extensive literature, as a welcome relief for research laboratories and colleges, which in turn will save time for other unsolved problems along those lines. The recently published work of references by the well-known English corrosion investigator, Vernon, entitled "A Bibliography of Corrosion," facilitates the study of the literature on corrosion considerably.*

The present paper is to consider a particular part of this subject. It deals with the often-neglected question concerning the relations between corrosion and structure, especially with the problem of the much-discussed grain size.

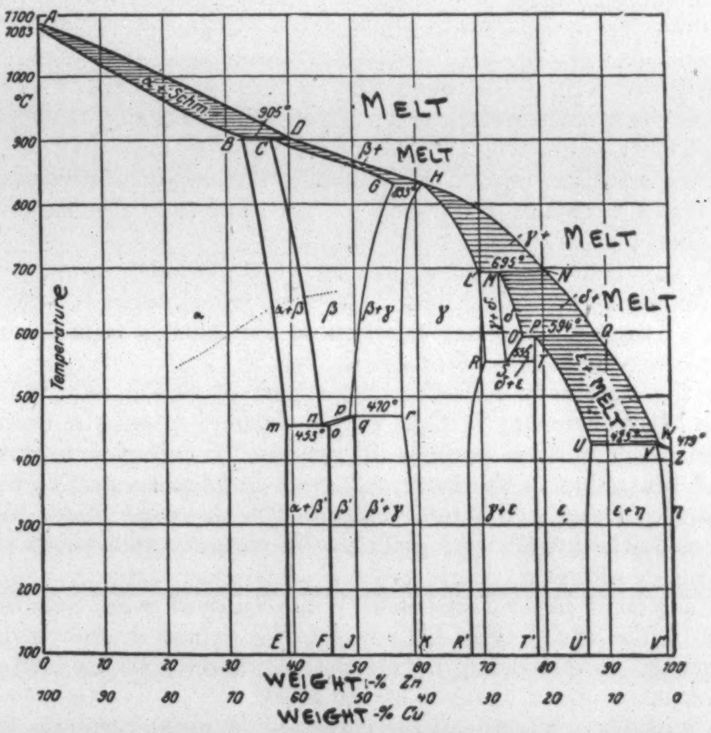
To begin with, the existing literature will be critically examined in this direction. Particular attention will be paid to the work of Lasche and of Basset. Later on the author's own practical investigations with corroded sheets of brass belonging to the boundary fields between the alpha and the alpha + beta phases will be discussed.

Examining these sheets, the deductive method was preferred, that is to say, the investigation started from corroded and uncorroded sheets which were used in industry under the same conditions. This way seems at the present to be the safer one in comparison with the inductive method of artificial imitation of corrosion, since it is very difficult to take into consideration all the factors during the experiment. It will remain the task of our colleges and research laboratories, as also in England and the U. S. A., to bridge in a systematic manner by means of modern instruments from the scientific experiment to the technical experiment in order to obtain an applicable working hypothesis, to assist industry by pointing out the methods for protection against corrosion.

How does annealing and consequently grain size, as well as the distribution of substance at the grain boundaries, influence the starting of corrosion?

The numerous publications contain the most contradictory viewpoints.

This is covered in an unpublished literary study of the Metallhüttenmännisches Institute of the Technische Hochschule, Aachen, by H. Masukowitz.[1]



Constitution Diagram of Copper-Zinc Alloys According to O. Bauer and M. Hansen

A brief survey is also given by W. Köhler[2] in the introduction of his work on the influence of the grain size of brass and bronze on corrosion resistance in heated salt and acid solutions.

Corresponding to the constitutional diagram, the different kinds of brass must be separated from each other according to the various phases, as, for instance, red-tombac, semi-tombac and extrusion-brass as these are called in practice, corresponding to the following areas in the diagram:

1. Copper-rich alpha-field (100–90% Cu).
2. Medium alpha-field (90–67% Cu).
3. Boundary zone between the alpha and the alpha + beta field (67–60% Cu).

We will refer to this classification later on evaluating the American experiments of Basset and Davis.

Furthermore, the following factors must be taken into consideration with the critical viewpoint:

1. Plastic treatment (amount of rolling).
2. Heat-treatment (grain size, influence of quenching heterogeneous substance at the grain boundaries).
3. Corrosion method (deductive, inductive). If deductive, consideration of all influencing factors, condition of delivery and manner of identifying the corrosion. If inductive, statements about starting material, method of testing, apparatus and choice of corroding media.

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* See "Book Reviews," METALS & ALLOYS, July, 1929, page 32.—EDITOR'S NOTE.

Relations between Grain and Corrosion

In his chapter, "Ungeeignetes kristallinisches Gefüge," A. Pollit[3] claims the tubes should be heat-treated at 350° ± 25° C. in oxidizing atmosphere after drawing of tubes in case of 70/30 brass and Admiralty Alloy. Thus the internal stresses are relieved and on the other hand a considerable grain growth is prevented. The heat treatment first proposed by Shaw Sparrow protects the material against intercrystalline corrosion. Ulick Evans[4] clearly outlines the corrosion of alpha + beta brass in his well-known book, "Corrosion of Metals," and calls attention to the investigations of Ramsay[5] and Donovan and Perks[6] who proved the low resistance of the beta phase undergoing porous sponge-like alterations and called attention to a suitable thermal treatment.

According to Goos[7] the Corrosion Committee of the German shipping trade demands in its specifications uniform grain in brass condenser tubes. According to his statements the specifications of the American Navy prescribe a limit in grain size of 0.02 mm.

Hofer[8] points out that in accordance with American experience a medium grain size of 0.035–0.045 mm. (corresponding to normal working and heat treatment) would favorably resist corrosion.

Philippi[9] lays stress upon the fact that besides the composition of the alloy it is its methods of production which are of greatest importance, and states that 70/29/1 brass, which is by nature harder and small grain sized, is consequently more stable against corrosion.

Schulz[10] emphasizes the influence of casting, of the structural distributions of the small amounts of additions, and of the temperature of rolling and heat treatment. He says that according to American experiments, which have been checked by the English Corrosion Committee, a material annealed at only 400° C., but held for a longer time in the annealing furnace, exhibited a better grain and a greater resistance to corrosion than if annealed at a higher temperature.

M. von Schwarz[11] found, in case of a 71/28/1 tin-brass with a coarse-grained alpha phase, appearances of surface corrosion. By exchange of personal experiences the author found a most complete coincidence of opinions.

In the discussion following the report of Desch and White,[12] "The Microchemistry of Corrosion," Garland raised the question of grain size and he assumes an increase of corrosion in case of 53/47 brass due to the increased grain boundaries and to metastability. Desch and White disagree with this conception. With respect to the influence of grain size in case of alpha alloys there was no experience.

In a second paper Desch and White[13] investigated pure alpha brass of the 70/30 type. As was to be expected, they noticed differences in corrosion between the inhomogeneous and the homogeneous grain in favor of the latter.

In a third publication[14] on corrosion of alpha + beta brass definitions already known on the primary attack of the beta constituent are given.

In his classic work, "Konstruktion und Material im Bau von Dampfturbinen," Lasche[15] shows excellent pictures of corroded brass in natural colors arranged according to their resistance to electrolytic destruction. The statements are quite clear:

70/30 brass with uniform coarse grain shows good corrosion resistance.

70/30 brass, according to Lasche with homogeneous grain alpha solid solution, fine-grained material but in reality irregular, fine and coarse grain, is not as resistant as the material mentioned above. Likewise 70.5/28/1.5 tin-brass revealed corrosion beginning along the grain boundaries.

65/35 (Muntzmetal) irregular large grain with remains of the alpha phase at the boundaries was changed into porous copper by dezincification.

61/39 and 60/40 brass disclosed corrosion of the beta constituent.

Lasche's attempt to prove that a coarse crystalline material would resist electrolytic influences better than a small, grain sized, hard one, ends with a wrong conclusion. It is true he connected small-grained elements against coarse-grained ones in an acidulated NaCl solution and obtained primary solution of the fine crystalline substance as was to be expected.

In the very valuable discussion on the report of Lasche about "Anfressungen an Kondensatorrohren," Czochralski thoroughly discusses the problem of structure in the various phases of brass, especially that of the alpha constituent.

At the symposium "Säurefeste Legierungen"[16] the important question of the grain size was frequently mentioned as, for instance, by Koch.

P. T. Bruehl[17] after extensive experiments detects a corrosive stability of the 70/30 brass in case of a small, grain sized material and a maximum of corrosion with coarse grain; this work, however, is not basic enough to permit positive conclusions.

Wurstemberger[18] like Desch and White emphasizes the greater resistance of brass containing only one phase, the importance of uniform grain, the danger of the appearance of the beta phase dispersely distributed along the grain boundaries of the alpha constituent due to too high temperatures.

The work of Anderson and S. H. Brooks[19] on "The Influence of the Grain Size of Alpha + Beta Brass" starts with an electrolytic method of rapid etching of a 66.27% Cu, 1.2% Sn brass which received ten different grain sizes from 0.01–0.1 mm. by means of systematic annealing. A direct dependence on grain size could not be recognized. Both investigators therefore conclude theoretically on a refutation of the amorphism theory since small grain with hypothetically much amorphous intermediate substance should be more liable to corrosion than coarse grain. We, therefore, can agree with the objective criticism of Hanser[20] stating that these experiments are not sufficient to obtain a definite answer to the question of the grain size.

A. Schimmel[21] in his more general treatise, "Messing als Werkstoff für Kondensatorrohre," is of opinion that coarse granular tubes are locally more easily attacked than fine-grained ones. He calls attention to the publications of Lasche, but he draws theoretical conclusions which will lead to an opposite view point with respect to the grain size. Schimmel rightly believes that other explanations of Lasche's observations are also possible. This criticism has been mentioned before at the occasion of the critical discussion of Lasche's works. The conception of Schimmel on the uniform corrosion of alpha + beta brass is only partly true. The English investigator, W. H. J. Vernon, emphasized in a lecture before the Birmingham Metallurgical Society, "Notes on the Corrosion of Metals," that in his own tests the dezincification was accelerated in case of coarse grain (61.44 brass) and that this tendency to corrosion was diminished in fine crystalline material.[21a]

In his experiments on the influence of the grain size of brass and bronze upon the resistance to corrosion in heated salt and acid solutions, W. Köhler[2] denies a functional relation between the differences in the structure, due to annealing treatment, and corrosive stability. Nevertheless, his tests show an increased solubility (decrease of corrosion resistance) with increasing annealing temperatures. In addition the composition of his sheets, 70/30 and 70/29/1 brass, should be noticed.

The evolution of the investigations of Basset and his collaborator by Masukowitz is very interesting, and will be briefly summarized with several diagrams:

In Figure 1 the data of accelerated corrosion tests by Basset and Bedworth[22] (spraying method) are reproduced, disclosing the relation between time and composition.

After four weeks we only recognize a uniform corrosion attack,

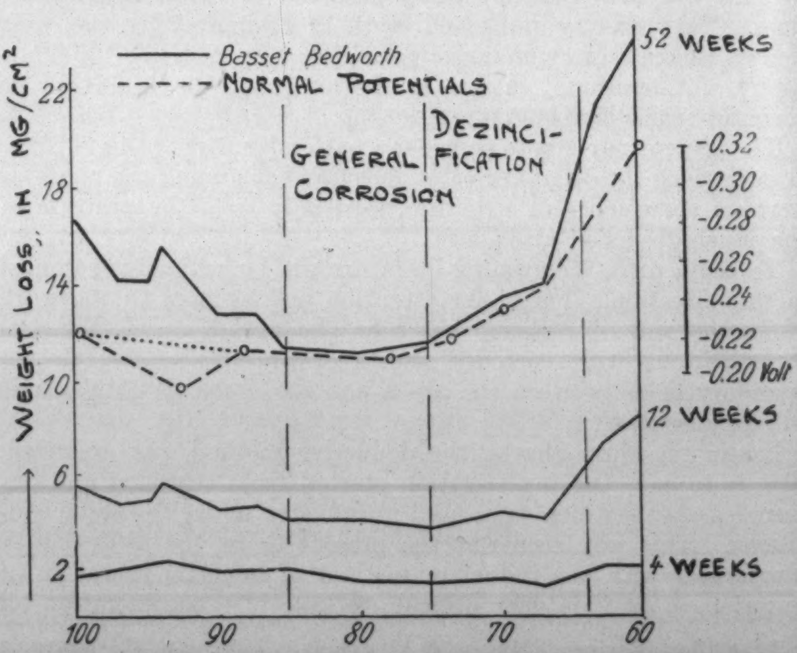


Figure 1—Accelerated Corrosion Tests (Basset and Bedworth)

if we disregard that small minimum of corrosion at 70–80% Cu. After twelve weeks we notice a decided rise of the curve, that is to say, an increased corrosion between the alpha and the alpha + beta field. After 52 weeks this effect becomes still more evident. In the copper-rich field there is a continual decrease, in the midst of the alpha field we have a horizontal course with general corrosion and, finally, there is a remarkable increase of dezincification at the boundary between the alpha and the alpha + beta field. The normal potential curve of Bauer and Vogel plotted with the normal calomel electrode at 18° C. in 1% NaCl solution coincides with the curve of these 52 weeks.

Basset and Davis[23] furthermore investigated brasses of various compositions between 100 and 60% Cu in form of cold rolled initial alloys annealed at different temperatures and rolled with different drafts and finally exposed for 8½ years to the corroding action of sea-water (Figure 2).

If we differentiate between the three zones: (*a*) 100–90% Cu, (*b*) 90-68% Cu, (*c*) 68–60% Cu, the following holds for group (*a*):

In the copper-rich field, annealing at low temperatures (600° C.) proved favorable. Heavy rolling resulted in further improvement. The second group (*b*) in the midst of the alpha field withstood these corrosion tests more favorably. All annealing treatments improved equally well and the grain size had no influence (Figure 3). Slight rolling induced a faint improvement. The third group (*c*) in the boundary field alpha, and alpha + beta is of greatest importance for the present paper. In this field annealing was of great influence. The highest values of corrosion in these alloys occur at annealing temperatures which exactly correspond to the line of intersection between the alpha and beta field, that is to say, at 650 and 750° C. The small particles of beta brass at the grain boundaries, like slight impurities, actively initiate corrosion.

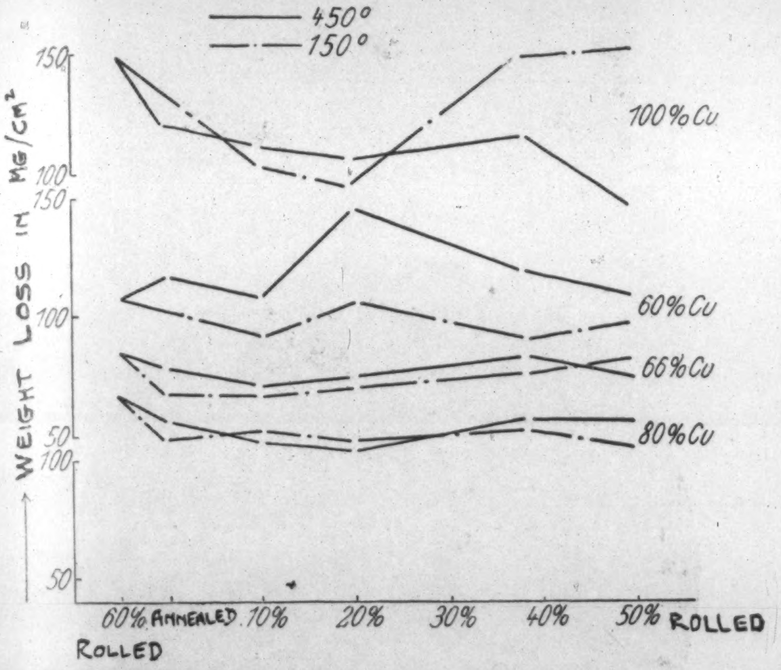


Figure 2—Influence of Rolling on Corrosion (Basset and Davis)

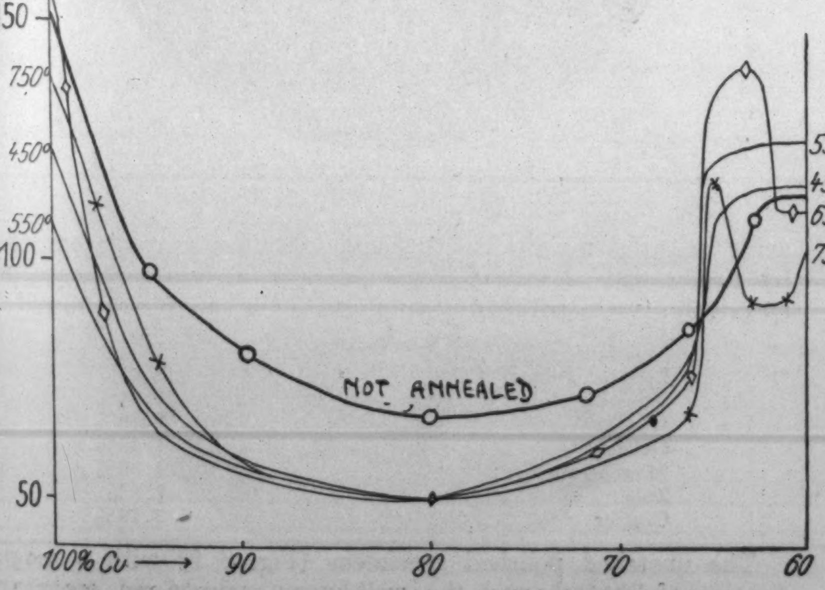


Figure 3—8½-Year Corrosion Tests of Brass (Basset and Davis)

Experimental Part

The investigations deal with typical corrosion appearances on automobile radiator sheets.

For the first series of experiments sheets, of brass were used which were put in their place under the same conditions. In spite of the same conditions, very pronounced corrosion took place after a very short time in one case, while other sheets resisted corrosion perfectly.

Figure 4 represents a typical corroded 63 brass sheet. These strongly corroded sheets (material 1 and 2) show on the inner side, where they always had been in contact with the flowing cooling water, pronounced corrosion effects in form of numerous grayish white point-form growths. Figure 5, after slight pickling with nitric acid, salmon-red spots of copper could be recognized at the same place on a golden-yellow matrix of brass where the products of corrosion had been dissolved. Figure 6 represents a typical dezincified spot of copper of a polished specimen after etching with ammonia and hydrogen peroxide at 100 magnification.

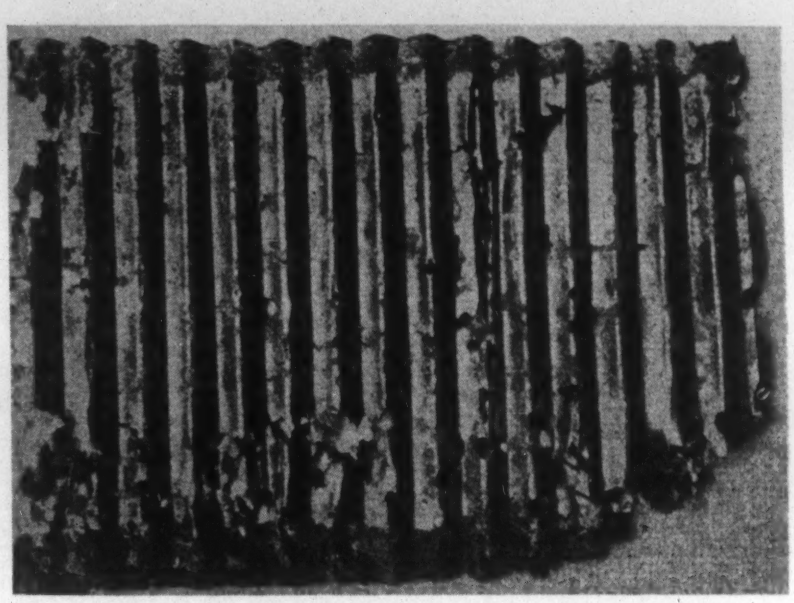


Figure 4—Typical Corroded Radiator Sheet of 63 Brass

This strong, point-form dezincification is not only perceptible at the inside, but there is, also, a distinct red spottedness on the outside. In some cases the "copper plug" went clear through the whole sheet cross-section. There was a distinct formation, pronounced holes and crevices. The products of corrosion, which were carefully removed and saved, proved to be chiefly basic zinc carbonates.

The chemical analysis of the unattacked parts of the corroded sheets disclosed:

	Cu	Zn	Pb	Fe	Sn	Ni	As
Material 1	64.14	35.68	0.0	0.18	0.01	..	..
Material 2	62.81	36.97	0.0	0.12	0.04	..	..

The sheets obviously belong, according to their chemical composition, to the boundary fields between the alpha and alpha + beta phases of the brass constitutional diagram. The longitudinal sections of the sheets 0.2 mm. thick exhibit an irregular grain-structure of predominating alpha brass after etching with ammonia and hydrogen peroxide. Figure 7 shows an uncorroded spot of the same sheet. Judging by the coarse grain, an annealing at too high temperatures must have taken place so that the beta constituent shows up at the grain boundaries (see diagram). The corrosion always starts primarily along the boundaries between the coarse crystals and surrounds the crystal complex which soon dissolves. The other radiator sheet, which turned out well under the same conditions, was of the following composition:

Cu	Zn	Pb	Fe	As	Sn	Ni
63.16	36.38	0.34	0.07	..	..	..

It proved to be a pure 63 brass. The polished specimen (Figure 8) reveals pure alpha crystals in a uniform, fine granular arrangement after etching with ammonia and hydrogen peroxide.

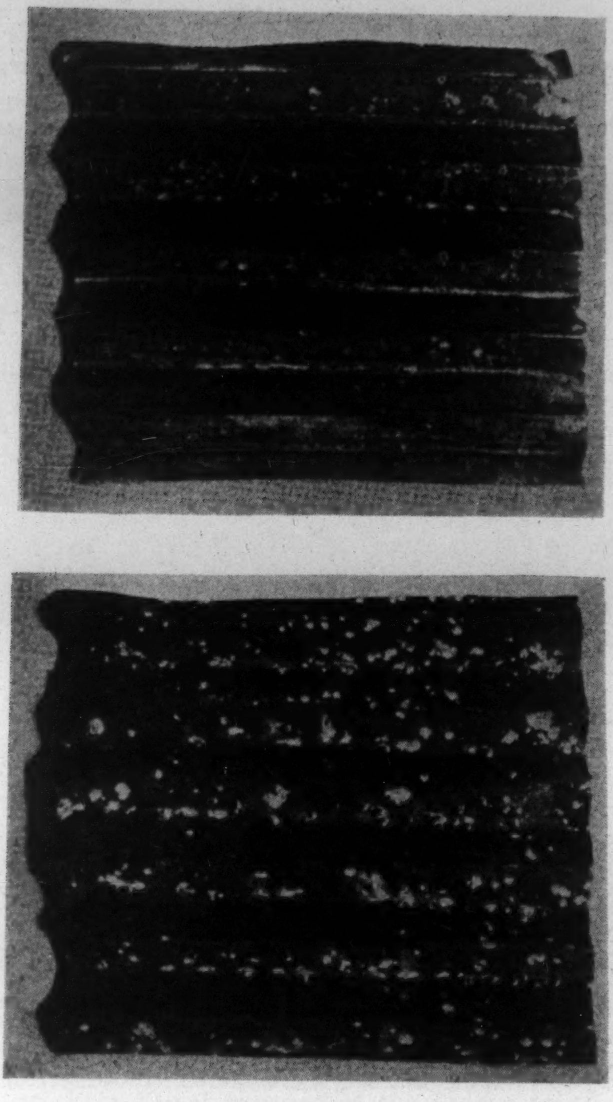


Figure 5—Corroded Radiator Sheet 64.14 Cu. Upper: Original State. Lower: Etched

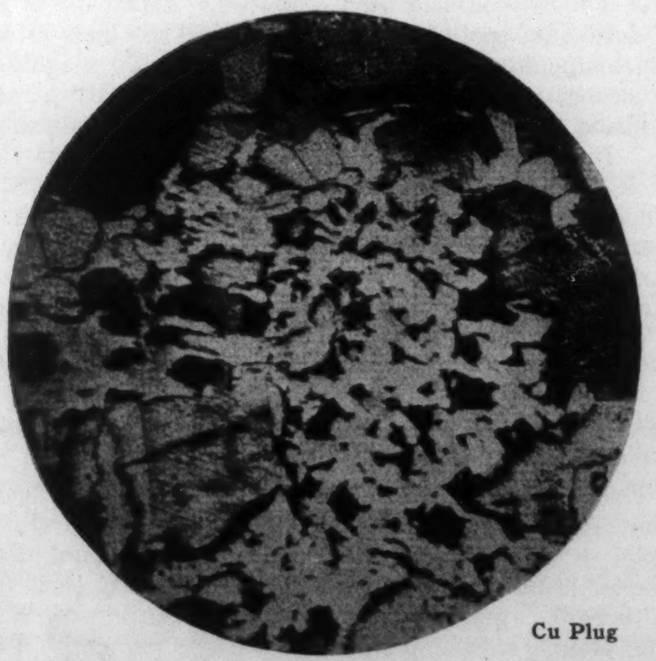


Figure 6—Irregular Coarse Grain of Corroded 63.7 Brass Sheet

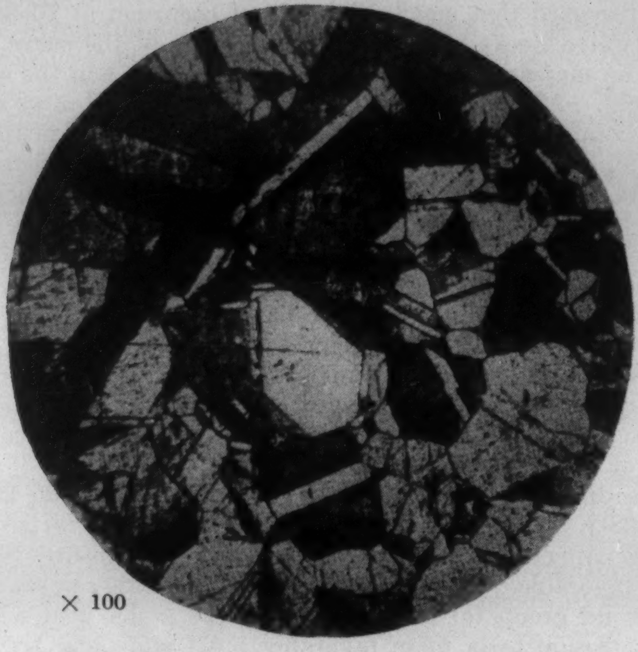
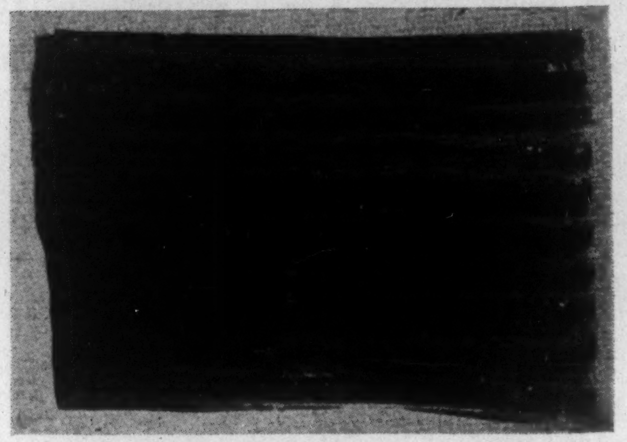


Figure 7—Irregular Coarse Grain in 63.7 Brass Sheet



Original

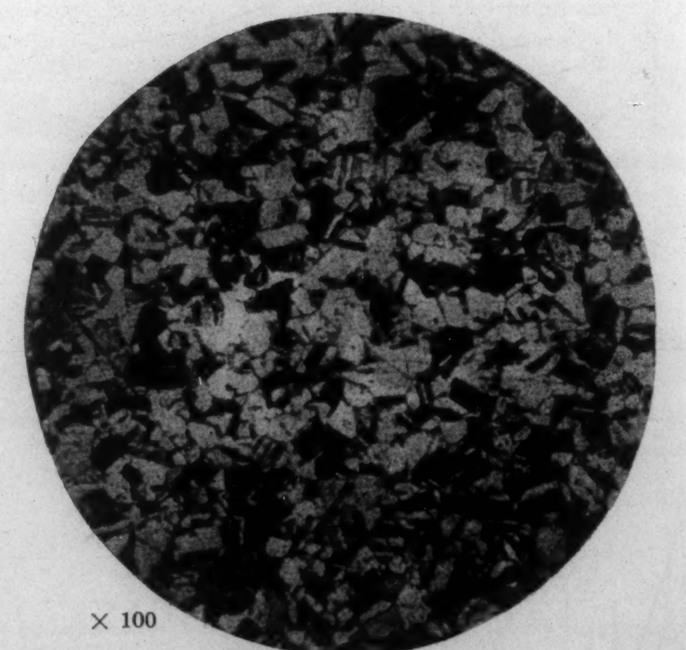


Figure 8—Uniform Fine Grain Stainless 63 Brass Sheet

Results from the First Series of Investigations. Pronounced corrosion occurred with the non-uniformly coarse grain in the case of 64 and 63 brass. The 63 brass built up of uniform fine grain was resistant to corrosion.

In the second series there were heavily corroded sheets of radiators of the following composition: 64.36% Cu, 0.053% Pb, 0.104% Fe, that is to say, sheets approaching material 1.

Analysis of the Corrosion Products

The products of the strongly corroded sheets were carefully removed.

The fine yellow-green powder did not completely dissolve in acids or aqua regia. The insoluble residues were decomposed by fusion with a mixture of sodium potassium carbonate, respectively, with potassium sulphate. The analysis showed:

Moisture	1.6%
Loss on ignition (CO_2)	8.9%
Silicon dioxide	22.84%
Iron	2.18%
Calcium	1.43%
Magnesium	4.36%
Zinc	7.8%
Copper	3.16%

The unetched polished specimens (Figure 9) with a magnification of 30× showed the well-known salmon-red spots and etching with copper ammonia chloride (magnification 100×) resulted in a coarse, granular, irregular structure with intercrystalline corrosion.

Evaluation. The heavily corroded sheets show a coarse, irregular structure. Corrosion sets in primarily along the grain boundaries.

The third investigated series included corroded sheets of coolers of 64.4 brass.

The sample of the sheet was covered by a rust-brown film. The products of corrosion were in a granular condition at the inside. The interior of the grains was white, the exterior parts were brown, probably zinc carbonates. The outside of the radiator sheets possessed the typical color of verdigris.

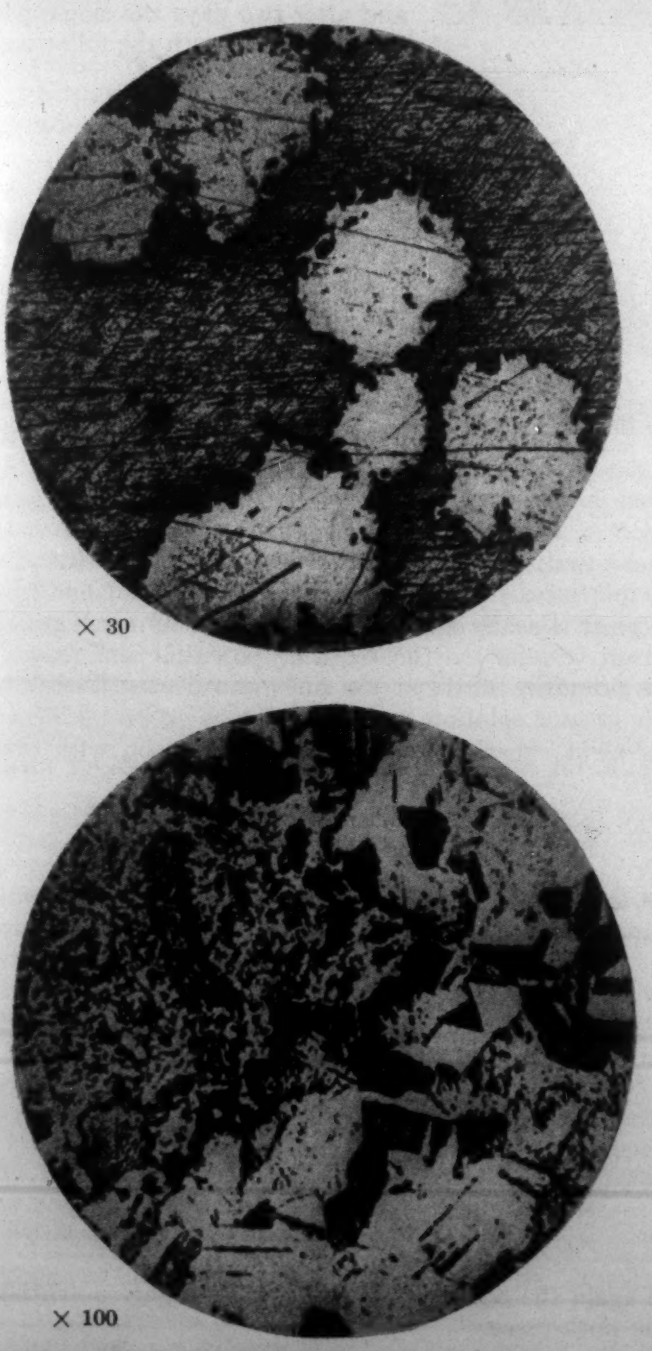
Clean Etching. In order to expose the corroded spots, the radiator sheets were pickled in nitric acid.

On a golden-yellow ground mass of brass, large dezincified red spots immediately appeared, which at the bent edge had nicely developed into salmon-like perforations (Figure 10).

Chemical Analysis. An exact chemical analysis of the brass was taken, as well as an average sample from non-corroded parts of the sheet, which gave the following percentages:

64.36%	Cu
Trace	Me
Trace	Pb
...	Ni
...	Sn
Balance	Zn

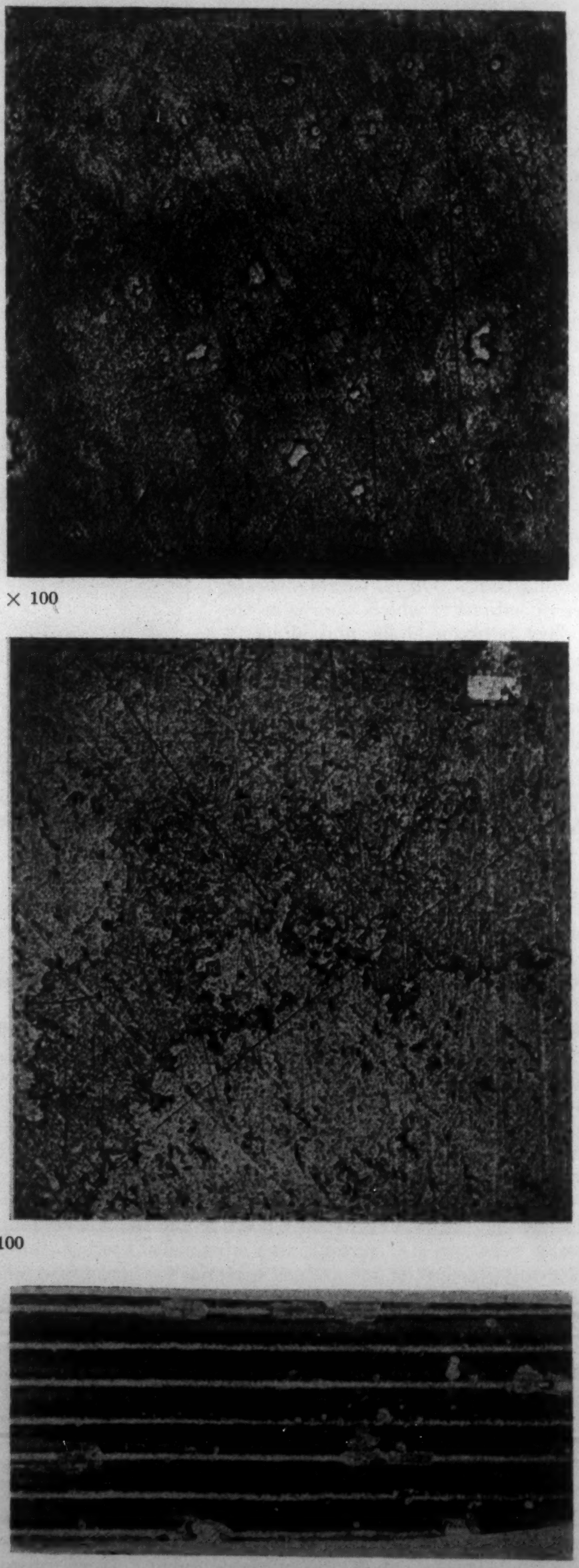
Metallographic Analysis. The specimen with a copper content of 64.36% belongs to the pure alpha phase. By annealing at too high temperatures above 750° C. it easily passes into the field of the alpha + beta phase. After quenching the sheet from this temperature, we, of course, get some beta brass in more or less dispersed form in the alpha region. The metallographic investigation confirms this theoretical consideration. Figure 10 shows a sample of the radiator sheet magnified 100×, polished in a horizontal section and etched for beta brass by ammonium persulphate. A large salmon-red dezincified spot with small red impregnations on a golden-yellow matrix can be distinctly recognized under the microscope. The light blue impregnations



× 30

× 100

Figure 9—Copper Ammonium Chloride Corroded 64.36 Brass Sheet



× 100

× 100

Figure 10—Corroded Radiator Sheet 64.36 Brass

of beta brass are of the same appearance but not dezincified. By carefully etching with ammonium persulphate at some unattacked spots of the beta brass, the beta constituent in an alpha matrix could clearly be developed.

A large disposed distribution of small beta particles, partly coagulated into larger parts, can be recognized.

Annealing homogenized this alloy; the beta phase totally dissolved.

Evaluation. In this case the incorrect annealing treatment with the metastable condition of distributed beta crystals was the cause of corrosion.

For the last group of tests corroded radiator sheets of the following analysis were used: 62.74% Cu, 0.009% Fe, trace of Pb. These sheets of 63 brass possessed striking localized corrosion areas. After pickling, very striking corroded drawing marks appeared. From the apparently corroded zones, samples were selected, magnified 600× and etched with ammonium persulphate; the specimens revealed the typical alpha + beta structure (Figure 11). Corrosion and dezincification primarily set in on the beta constituent as could obviously be recognized.

Evaluation. The strongly corroded sheet was over-annealed and showed the presence of many beta segregations, which are the nuclei of corrosion.

Summarizing. On all sheets of brass, the compositions of which were near the boundary between alpha and alpha + beta brass, heavy corrosion occurs particularly in case of irregular coarse grain.

Corrosion primarily sets in along the grain boundaries. To a great extent beta brass could be recognized as the starting point of corrosion at the grain boundaries. Uniform small grain exhibited great resistance to corrosion.

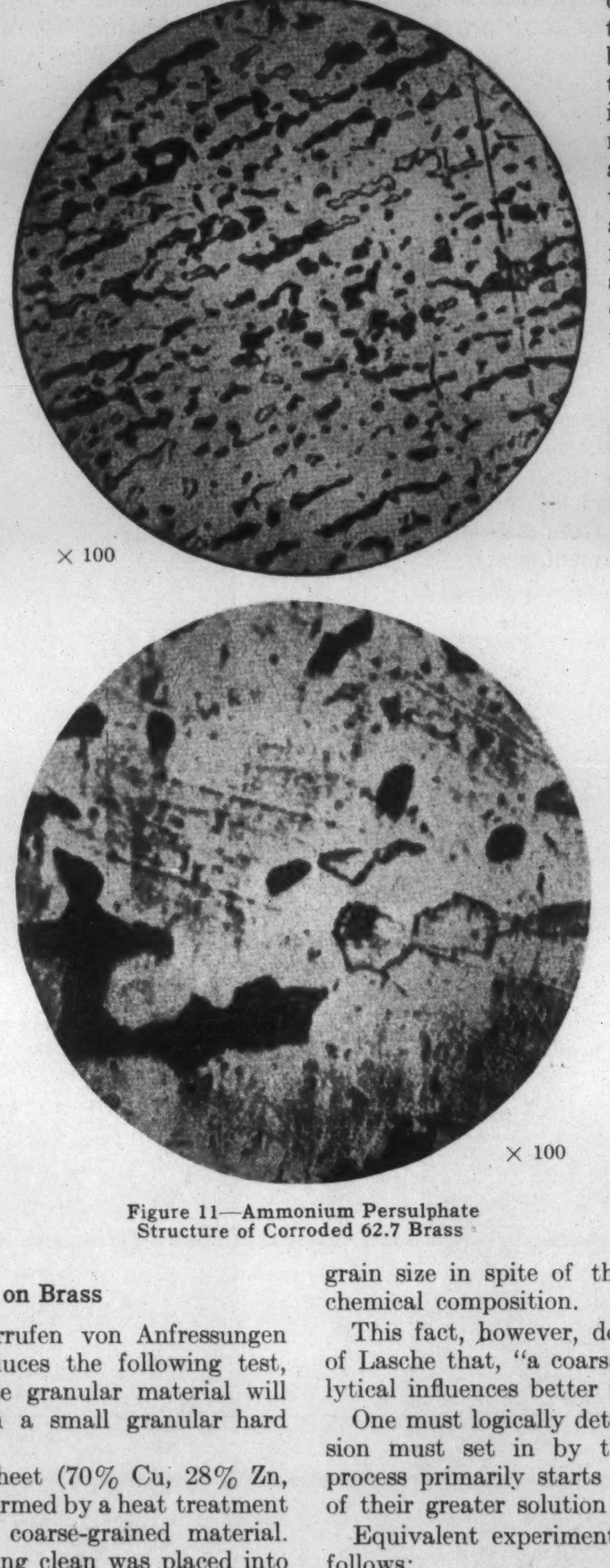


Figure 11—Ammonium Persulphate Structure of Corroded 62.7 Brass

Potential Measurements on Brass

In his chapter, "Künstliches Hervorrufen von Anfressungen durch örtliche Ströme," Lasche reproduces the following test, which is supposed to prove that coarse granular material will resist electrolytic influences better than a small granular hard one:

"A strip of very fine-grained brass sheet (70% Cu, 28% Zn, 2% Sn) from a condenser tube was transformed by a heat treatment at 700° C. in a Heräus furnace into coarse-grained material. This coarse crystalline piece after pickling clean was placed into an acidulated NaCl solution with cleansed, fine granular strip of the same size original material. The two were connected in circuit with a millivoltmeter of 100 ohms. A potential difference of 1–1.5 volts between the two materials showed that the coarse crystalline material was electrically positive and the fine crystalline one was negative. A current was obviously flowing through the electrolyte from the fine-grained material to the coarse-grained which caused the fine crystalline material to dissolve. These conditions remained unaltered during the whole period of observation (100 hours). Since the chemical composition of both electrodes was exactly the same, the resulting current could only be produced by the difference in mechanical properties, that is to say, the different number of crystal boundaries, which, of course, are harder than the core of the crystals.

"The mechanical defects mentioned above, which consist of local irregular compositions of segregations or of the defects, are caused by mere mechanical influences. Impressions produced mechanically, as is known, give rise to the so-called slip-bands of which a single crystal can exhibit quite a number. If we interpret each of these bands as a newly formed grain boundary and if we do not consider the material between the slip-bands as a part of that crystal but as a newly formed one, according to the above, we can explain the localized dezincification as a result of localized mechanical impressions. We thereby arrive at the conclusion, that condenser tube stock with very few grain boundaries, that is to say, coarse-grained material, is preferable from a chemical standpoint to a fine granular material due to the general corrosion of dezincification."

To control measurements of the potential difference of coarse and fine granular 70/28/2 Sn brass, by means of a Lasche galvanometer material of the same composition, brass was subjected to measurement of the single potentials by means of the known compensation method (with Oswald's Decade-rheostat, and capillary electrometer, calomel electrode).

In order to obtain differences in grain size, the material was annealed at 750° C. for 8 hours.

The fine- and the coarse-grained samples of the same chemical composition were suspended in an electrolyte of 0.5 *N* NaCl solution with 3.5% HCl and after two days the single potentials were measured with the following result:

Coarse granular sample	0.2389 volt
Fine granular sample	0.2345 volt
	0.0044 volt
Potential difference:	4.4 millivolts

The values exhibit a higher potential for the coarse-grained material with smaller solubility, and lower potential of the fine-grained material with a greater solution pressure. We obtain a potential difference due to the different grain size in spite of the fact that the pieces have the same chemical composition.

This fact, however, does not permit the erroneous conclusion of Lasche that, "a coarse-grained material will withstand electrolytical influences better than a fine-grained, hard one."

One must logically determine that in case of mixed grain, corrosion must set in by the existing potential differences. This process primarily starts at the fine-grained constituents because of their greater solution pressure.

Equivalent experiments have been carried on with brasses as follows:

83.62% Cu, balance Zn, traces of impurities
63 % Cu, balance Zn, traces of impurities

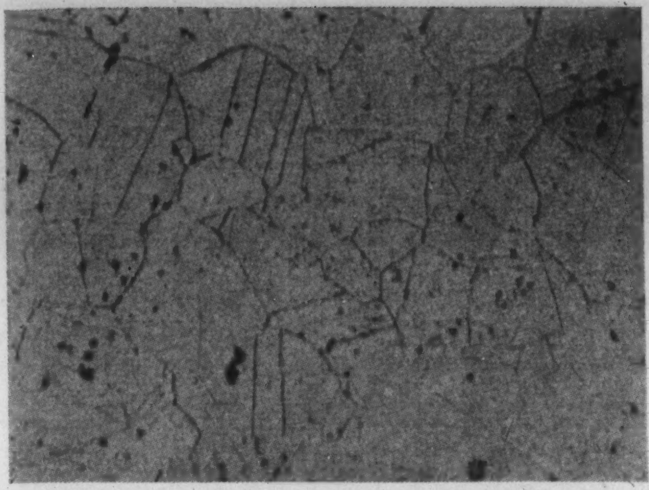
Heat treatment. The grain size of 63 brass is reproduced in photomicrograph 12. The following values were measured:

	Brass 63
Coarse grain	0.237
Fine grain	0.231
	0.006 volt = 6 millivolts

	Brass 83
Coarse grain	0.2128
Fine grain	0.2101
	0.0027 volt = 2.7 millivolts

It is again the coarse grain which gives higher potential differences in both cases.

The values prove, furthermore, that brasses from the copper rich part of the alpha field will be in a better condition with regard



× 100
63 Brass, Coarse Crystalline, Recrystallized

× 100
63 Brass, Fine Crystalline State of Delivery

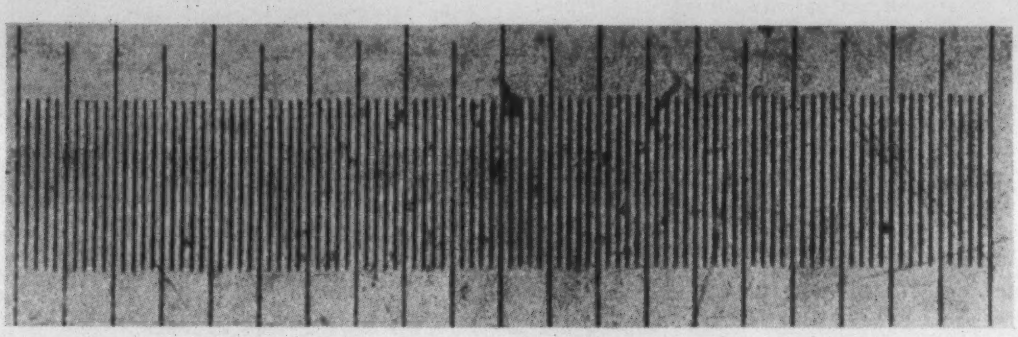


Figure 12
Scale: 100 Graduation Marks = 100 Mm.

to the potential difference than Admiralty alloy and 63 brass (as is to be expected the difference is greatest with the latter).

The potential values correspond directly to the directly measured data.

Conclusion

The experiments prove that homogeneous, fine crystalline 63 brass from the boundary fields of alpha/alpha + beta were more stable against corrosion than irregular, coarse granular brass. Potential measurements with brass of the same composition but various grain size disclose that differences in grain size suffice to initiate corrosion primarily.

The tendency to corrosion increases with increased amounts of substances at the grain boundaries, for instance in case of too high annealing temperature resulting in a coarse grain and agglomerated intermediate substance.

The general fact largely coincides with similar investigations on other metals and alloys. We will only mention the publications of Whyte,[24] who in case of coarse-grained, over-heated steel obtained a greater corrosion in comparison with normal, fine-grained steel. Denzo Uno[25] determines precisely the same results in his ideal systematic investigations on the artificial corrosion of the Japanese special alloy, Schakudo.

Suggestions to Avoid Corrosion in Brass Sheets for Radiators

1. In the choice of 63 brass, care should be taken in charging and melting down to obtain a content of 63 ± 0.02% Cu. A smaller content of copper should be avoided in all events. During initial rolling and at intermediate annealing, too high temperatures must be avoided. A temperature of 560° ± 10° C. should be maintained. One should aim at homogeneous fine grain.

2. Corrosion can be suppressed more easily by the choice of more resistant types of brass as, for instance, Admiralty alloy (70/29/1) or 70/30 brass, or by the application of Cu-Ni alloys, pure nickel or copper.[26]

It is a pleasant duty for me to heartily thank Professor Roentgen for his kind support of this work as well as my collaborators, especially E. O. P. Poettken, E. Felchner and H. Masukowitz for their cooperation.

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1,728,070	P. L. J. Miguet, St.-Julien-de-Maurienne, France, assignor to Société Électrométallurgique de Montricher. *Electric furnace (electrode mounting).* Dec. 23, 1927.
1,728,071	P. L. J. Miguet, St.-Julien-de-Maurienne, France, assignor to Société Électrométallurgique de Montricher. *Electrode for electric furnaces.* Dec. 23, 1927.
1,728,094	H. Wittek, Beuthen, Germany. *Process of reducing zinc ores.* Dec. 1, 1926.
1,728,095	S. Yoshimoto, Aki-Gun, Kochi-Ken, Japan. *Method of treating copper slag.* July 6, 1926.
1,728,104	Maurice Claude, Boulogne-Sur-Seine, France. *Blowpipe for cutting apparatus.* Mar. 8, 1928.
1,728,130	W. Mathesius and H. Mathesius, Charlottenburg, Germany. *Process of purifying gases from blast furnaces.* Dec. 30, 1925.
1,728,148	H. A. Wise Good, New York, N. Y., assignor to Wood Newspaper Machinery Corporation, New York, N. Y. *Machine for casting printing plates without a riser.* Apr. 30, 1926.

United States Reissues

Reissues from August 20, to September 10, 1929, inclusive

Reissue No.	Patentee, Subject of Invention, and Filing Date
17,410	F. B. Crosby, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. *Electrically-operated switch for the product of rolling mills.* Mar. 30, 1926. Original Apr. 22, 1924, filed May 17, 1920.
17,413	A. T. Kathner, Mount Lebanon, Pa. *Annealing and heat-treating furnace.* May 10, 1929. Original May 15, 1928, filed May 26, 1926.

Austrian Patents

Patent No.	Patentee, Subject of Invention, and Date of Beginning of Life of Patent
114,673	F. Krupp Grusonwerk Akt.-Ges., Magdeburg-Buckau, Germany. *Process for separating crude mineral products.* Jan. 15, 1928.
114,392	M. Roeckner, Mülheim-Ruhr, Germany. *Process for rolling tubing from hollow ingots and machine for working this process.* Apr. 15, 1929.
114,604	T. Kittl, Vienna, Austria. *Process for agglomerating material in the form of dust.* Apr. 15, 1929.
114,667	A. Wagner, Duisburg, and E. Hilgers, Düsseldorf-Oberkassel, Germany. *Device for introducing liquids, gases or dust into blast furnaces.* Apr. 15, 1929.
114,425	F. Krupp Akt.-Ges., Essen, Germany. *Furnace for hardening by nitriding.* Apr. 15, 1929.
114,424	K. Schmidt, Neckarsulm, Württemberg, Germany. *Process for making corrosion-proof alloys containing magnesium.* Apr. 15, 1929.
114,426	M. Gliksman, Paris, France. *Electric induction furnace.* Apr. 15, 1929.
114,527	H. Pfanhauser, Vienna, Austria. *Device used with copper-plating baths.* Apr. 15, 1929.
114,427	H. Canzler, Düren, Germany. *Welding alloy containing a noble metal, for welding copper.* Apr. 15, 1929.
114,428	Société Continentale Parker, Clichy, France. *Process for preparing or regenerating a rust-proofing bath.* Apr. 15, 1929.
114,677	F. Singer, Nuremburg, Germany. *Process for making elongated bodies, such as tubing, round bars, and shapes out of metals which can be extruded only at high temperatures.* Jan. 15, 1927.
114,404	Akt.-Ges. für aluminothermische und elektrische Schweissungen. *Process for making a tight and refractory mold around the ends of objects to be joined by casting highly heated metal around them, for example by the aluminothermic process.* Apr. 15, 1929.

British Patents

Complete Specifications Open to Public Inspection in Great Britain

Patent No.	Patentee, Subject of Invention, and Filing Date
316,208	I. G. Farbenindustrie Akt.-Ges. *Process of improving the resistance to corrosion of magnesium and magnesium alloys.* July 25, 1928.
316,212	E. Weir. *Production of malleable metal pipes from hollow blanks* July 25, 1928.
316,177	Mitsubishi Kogyo Kabushiki Kaisha. *Method of treating tin-containing material.* July 24, 1928.
316,129	Hartford-Empire Co. *Manufacture of refractory articles.* July 23, 1928.
316,259	F. Krupp Grusonwerk Akt.-Ges. *Extrusion presses.* July 26, 1928.
316,303	Davis Steel Process Corp. *Process of producing iron or steel directly from the ore and controlling the sulphur content thereof.* July 28, 1928.
316,196	R. A. Rognon. *Metal solders and their method of manufacture.* July 24, 1928.
316,659	E. F. Northrup. *Inductor furnaces.* Aug. 2, 1928.
316,229	International General Electric Co., Inc. *Electric furnaces.* July 25, 1928.
316,215	Vereinigte Stahlwerke Akt.-Ges. *Rolling-mills.* July 25, 1928.
316,571	E. Weir. *Production of malleable metal pipes.* July 31, 1928.
316,662	E. F. Northrup. *Electric furnaces of the inductor type.* Aug. 2, 1928.
316,555	F. Krupp Akt.-Ges. *Process for the production of age-proof welds on the fused welding method.* July 30, 1928.
316,556	F. Krupp Akt.-Ges. *Process for the production of age-resisting welded seams when welding age-resisting iron or steel alloys by the press-welding process.* July 30, 1928.
316,614	F. Krupp Akt.-Ges. *Welding wires.* Aug. 1, 1928.
316,562	British Thomson-Houston Co., Ltd. *Anodes for electric discharge devices.* July 30, 1928.
317,065	Mannesmannröhren-Werke. *Seamless tubes.* Aug. 10, 1928.
316,997	N. Leonard. *Castings of large dimensions, especially frames for railway rolling-stock.* Aug. 8, 1928.

Patent No.	Patentee, Subject of Invention, and Filing Date
317,035	Siemens & Halske Akt.-Ges. *Process for the extraction of rhenium* Aug. 9, 1928.
316,964	Youngstown Sheet & Tube Co. *Welding.* Aug. 7, 1928.
316,967	E. F. Northrup. *Inductor furnaces.* Aug. 7, 1928.
317,001	Metallges. Akt.-Ges. *Process of treating ores, metallurgical products, or the like.* Aug. 8, 1928.
317,002	American Foundry Equipment Co. *Tumbling-mills.* Aug. 8, 1928.
316,969	Hirsch Kupfer- und Messingwerke Akt.-Ges. *Process for carrying out the electrolysis of fused electrolytes, and apparatus for carrying out such process.* Aug. 7, 1928.
316,986	Trent Process Corporation. *Apparatus for producing metals from their oxide ores.* May 11, 1928.
317,361	P. L. &. M. Co. *Welding method and composition.* Aug. 14, 1928.
317,399	H. H. Stout. *Pyrometallurgical copper refining.* Aug. 15, 1928.
317,449	Harbison-Walker Refractories Co. *Refractory materials and the process of making the same.* August 16, 1928.
317,373	F. Krupp Akt.-Ges., Friedrich-Alfred-Hütte. *Process of treating iron baths in steel furnaces.* Aug. 14, 1928.
317,493	A. Glazunov. *Process of removing the last traces of oxygen from iron, steel or such alloys.* Aug. 18, 1928.

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(Complete Specifications Accepted)

Patent No.	Patentee, Subject of Invention, and Filing Date
316,329	H. E. Potts (communicated by Electro Metallurgical Co.). *Process of decarburizing ferro-alloys.* Mar. 27, 1928.
316,164	L. Kluger and Oester-Reichische Schmidtstahlwerke Akt.-Ges. *Acid-resisting iron alloys.* Apr. 20, 1928.
316,244	S. P. Bowen. *Tuyères for blast furnaces or the like.* Apr. 26, 1928.
316,063	A. R. Powell, E. C. Deering, and Johnson, Matthey, & Co., Ltd. *Treatment of ores, metallurgical products, residues, and the like for the recovery of precious metals.* May 1, 1928.
316,360	W. R. Hume. *Electric welding-machines.* May 7, 1928.
316,394	W. H. Hatfield and H. Green. *Metal articles for use in chemical and like processes, and alloys therefor.* June 27, 1928.
316,401	A. Rowland-Entwistle. *Production of metallized surfaces.* June 29, 1928.
316,404	W. S. Millar. *Process for the treatment of oxide iron ores.* July 3, 1928.
316,419	Platt Bros. & Co., Ltd., and A. E. Jones. *Method of, and means for manufacturing bolts and other headed objects.* July 13, 1928.
316,446	G. Monaghan. *Anodes for electrolytic baths.* Aug. 9, 1928.
299,773	E. Abel. *Lead-bearing metals containing nickel and copper.* Oct. 31, 1927.
305,201	Vanadium Corporation of America. *Vanadium alloys.* Feb. 2, 1928.
306,478	F. Krupp Grusonwerk Akt.-Ges. *Discharge troughs for cooling-beds of rolling-mill installations.* (Addition to 263,145.) Feb. 21, 1928.
316,514	C. J. Rhodes. *Presses for sheet metal.* Feb. 15, 1929.
276,011	W. Schrobsdorff. *Method of producing alloys of very refractory carbides.* April 23, 1928. (Convention date not granted.)
292,094	H. E. Potts (communicated by Ternstedt Manufacturing Co.). *Chromium plating.* May 11, 1928. (Convention date not granted.)
316,714	W. A. Hiscox. *Devices for screening minerals and the like.* May 19, 1928.
316,720	J. P. Haley and J. H. Pinder. *Heat-treatment of metallic wire or strip.* May 24, 1928.
291,455	P. E. Bunet and Aciéries de Gennevilliers. *Magnetic-core induction furnaces.* June 2, 1927.
291,456	P. E. Bunet and Aciéries de Gennevilliers. *Induction furnaces.* June 2, 1927.
293,749	I. G. Farbenindustrie Akt.-Ges. *Manufacture of finely subdivided metals.* July 11, 1927.
316,753	A. G. Meeze. *Application of the fractionate combustion principle to the firing of blast furnaces.* July 10, 1928.
299,388	L. Renault. *Magnetic sclerometers.* Oct. 25, 1927.
295,991	Electrolytic Zinc Co. of Australasia, Ltd. *Manufacture of bearing-metal.* Aug 22, 1927.
302,305	Siemens & Halske Akt.-Ges. *Tapping-device for electrical furnaces.* Dec. 14, 1927.
304,752	Aluminium, Ltd. *Method of, and apparatus for casting duplex ingots.* Jan. 27, 1928.
316,835	R. Muller, Jr. *Muffle furnaces for flameless combustion.* Dec. 4, 1928.
317,102	A. E. White (communicated by Acme Steel Co.). *Method of, and mill for rolling metal strips and sheets.* March 6, 1928.
316,922	H. A. Livingstone. *Pulverization and separation of cereals, minerals, and the like.* May 5, 1928.
291,025	R. Ambronn. *Apparatus for electrically exploring the ground or soil.* May 24, 1927.
317,028	H. A. Gill (communicated by H. T. Richardson). *Sandcores for use in casting screw-threaded metal articles, and apparatus and methods for producing such cores.* May 9, 1928.
317,031	A. Carpmael (communicated by I. G. Farbenindustrie Akt.-Ges.). *Manufacture of potassium.* May 9, 1928.
317,137	C. H. R. Gower and S. O'Brien & Partners, Ltd. *Electrolytic deposition of chromium.* May 15, 1928.
317,140	A. Carpmael (communicated by I. G. Farbenindustrie Akt.-Ges.). *Welded joints.* May 15, 1928.
317,141	A. A. Lockwood. *Concentrating or separating solid substances.* May 15, 1928.
302,642	Chemische Fabrik Weissenstein Ges. *Thermal treatment of non-cementable metals and alloys.* Dec. 19, 1927.
317,180	S. Westberg. *Method of refining metal and alloys.* June 25, 1928.
317,235	M. D'A. Clark (communicated by Bendix Brake Co.). *Method of, and apparatus for welding.* Aug. 21, 1928.
317,236	M. D'A. Clark (communicated by Bendix Brake Co). *Welding apparatus.* Aug. 22, 1928.
299,375	Soc. Anon. Le Nickel. *Electrolytic extraction of metals.* Apr. 13, 1927.
305,197	I. G. Farbenindustrie Akt.-Ges. *Process of improving the resistance to corrosion of magnesium alloys.* (Addition to 287,450.) Feb. 2, 1928.
301,043	British Thomson-Houston Co., Ltd. *Mechanism for feeding wire in general, and in particular, for feeding a welding rod or wire in automatic or semi-automatic welding-machines.* Nov. 23, 1927.
313,003	Landis Machine Co. *Means for feeding bolt blanks and like articles in succession automatically.* Nov. 28, 1928.
317,110	R. Grah. *Plating with chromium.* June 22, 1928.
317,378	J. Schmeller. *Method and apparatus for reworking finely-divided metal particles.* Feb. 13, 1928.
317,341	Balz Erzrostung Ges. and G. Balz. *Mechanical kilns.* (Addition to 288,823.) April 14, 1928.
317,382	F. Jorday. *Process for rolling-out sheet and hoop or band iron.* May 10, 1928.
317,416	A. L. Mond (communicated by I. G. Farbenindustrie Akt.-Ges.). *Method of charging electrical furnaces.* May 14, 1928.
292,164	Meehanite Metal Corp. *Method for improving the character of gray iron castings by graphitization.* June 16, 1927.
317,595	Woodall-Duckham, Ltd., and A. M. Duckham. *Method and apparatus for the repair of concrete or like structure, furnace linings, or the like.* July 5, 1928.
295,319	P. Lechler. *Method of preventing corrosion of submerged iron.* Aug. 9, 1927.
317,652	A. Knaff, L. Mayer, and P. Gredt. *Production of ore briquettes.* Sept. 8, 1928.
317,665	J. B. Read and M. F. Coolbaugh. *Method of roasting sulphide minerals.* Oct. 2, 1928.
317,688	E. Gathmann. *Ingot molds and ingots.* Nov. 21, 1928.
314,370	E. Kamp. *Production of forged shafts.* June 26, 1928.

Canadian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
292,082	W. C. Eggert, Latouche, Alaska. *Ore separator.* Jan. 18, 1929.
292,144	The Aluminum Company of America, Pittsburgh, Pa., assignee of A. B. Norton, Cleveland, Ohio. *Metal mould.* Jan. 21, 1928.
292,153	The British Aluminum Company, Ltd., assignee of A. G. C. Gwyer, both of London, England. *Aluminum alloy.* Oct. 29, 1924.
292,154	The British Aluminum Company, Ltd., assignee of A. G. C. Gwyer and H. W. Lewis, all of London, England. *Alloy.* Jan. 22, 1924.
292,179	The Globar Corp., Niagara Falls, N. Y., assignee of H. N. Shaw, Milwaukee, Wis. *Electrical furnace.* Aug. 31, 1926.
292,193	The Merrill Co., San Francisco, Calif., assignee of L. D. Mills and T. B. Crowe, Palo Alto, Calif. *Cyanide recovery process.* Oct. 4, 1928.
292,215	The Sulphur and Smelting Corp., Dover, Del., assignee by mesne assignments of E. W. Westcott, Niagara Falls, N. Y. *Treating sulphide ores.* Apr. 27, 1927.
292,234	F. M. Simonds and A. F. Hyde, assignee of one-half interest, both of New York, N. Y. *Apparatus for magnetic separation.* Mar. 12, 1927.
292,239	H. T. Richardson, New York, N. Y., assignee of J. V. Puccini and W. L. Guise, both of Dover, N. J. *Casting method and apparatus.*
292,255	H. E. Bakken, Niagara Falls, N. Y. *Metal purification.* July 16, 1927.
292,334	The Allied Process Corp., assignee of W. C. Smith, both of New York, N. Y. *Casting device.* Apr. 8, 1929.
292,356	The Canadian General Electric Co., Ltd., Toronto, Ont., assignee of C. L. Ipsen, Schenectady, N. Y. *Electric arc welding machine.* Aug. 9, 1927.
292,377	The Guggenheim Bros., assignee of A. H. Fischer, both of New York, N. Y. *Flotation process.* Apr. 11, 1927.
292,378	The Guggenheim Bros., assignee of A. H. Fischer, both of New York, N. Y. *Flotation process.* Apr. 11, 1927.
292,379	The Guggenheim Bros., assignee of A. H. Fischer, both of New York, N. Y. *Flotation process.* Apr. 11, 1927.
292,430	V. M. Goldschmidt and K. Stenvik, both of Oslo, Norway. *Casting mold (made of olivine and a binder).* Jan. 15, 1929.
292,431	P. F. M. Aubert, A. J. P. Duval, and H. A. M. Duval, all of Paris, France. *Metal hardening method (partial protection of objects to be nitrided).* Mar. 12, 1928.
292,434	P. Hustadt and K. Hustadt, both of Remscheid-Hasten, Rhld., Germany. *Heater for a tempering machine.* Oct. 19, 1928.
292,464	R. Greaves, Wallasey, Cheshire, England. *Magnetic separator.* Dec. 14, 1928.
292,492	T. Morgan, Prestatyn, England. *Tinplate packing method.*
292,501	W. Reuss, Mannheim, Germany. *Aluminum soldering and welding medium.* Nov. 3, 1928.
292,532	The Aluminum Company of America, Pittsburgh, Pa., assignee of R. S. Archer and W. L. Fink, Cleveland, O. *Aluminum-beryllium alloy.* Nov. 19, 1927.
292,565	The Globar Corp., Niagara Falls, N. Y., assignee by mesne assignments of F. Eichenberger, Aarau, Switzerland. *Process of producing elements usable for electrical heating resistances.* June 4, 1925.
292,612	The Stoody Co., assignee of W. F. Stoody, both of Whittier, Calif. *Alloy (welding alloy of Fe-Cr-Mn-Si).* Apr. 15, 1929.

Danish Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
40,381	A. Geyer, Paris, France. *Process for making aluminum alloys.* Feb. 2, 1928.
40,384	The New Jersey Zinc Co., New York, N. Y. *Conveying briquettes in metallurgical processes.* Feb. 28, 1927, in the United States Mar. 25, 1926.

Patent No.	Patentee, Subject of Invention, and Filing Date
40,421	Electrical Research Products, Inc., New York, N. Y. *Process for making a magnetic material containing nickel and iron for increasing the self-inductance of signal conductors.* (Addition to No. 38,799, filed May 8, 1922.) May 15, 1928, in the United States Aug. 16, 1921.
40,466	H. J. Garnett, Lymne, Kent; J. A. Holden, Sunnyside, Essex; and W. S. Smith, Newton Poppleford, Devon. *Quaternary alloys for loading telegraph and telephone cables.* Nov. 5, 1927, in Great Britain Nov. 6, and Dec. 17, 1926.
40,497	I. Rennerfelt, Djursholm, Sweden. *Electric resistance furnace.* Dec. 29, 1926.
40,500	Electrical Research Products Co., New York, N. Y. *Process for treating magnetic alloys containing nickel and iron.* Aug. 1, 1925.
40,504	American Radiator Co., New York, N. Y. *Shaft furnace for treating metals and ores.* Mar. 31, 1928, in the United States Apr. 19, 1927.

French Patents

Approximate Date of Publication: Nov. 15 to Dec. 1, 1929

Patent No.	Patentee, Subject of Invention, and Filing Date
668,806	Société Anonyme Robivir, assignee of H. E. J. A. Roche and L. M. A. Bidreman. *Prospecting by means of radiations.* May 19, 1928.
668,807	Société Anonyme Robivir, assignee of H. E. J. A. Roche and L. M. A. Bidreman. *Prospecting by means of radiations.* May 19, 1928.
668,808	Société Anonyme Robivir, assignee of H. E. J. A. Roche and L. M. A. Bidreman. *Prospecting by means of radiations.* May 19, 1928.
668,938	Société Union des Graphites, Tananarive, Madagascar. *Apparatus for the flotation of graphite.* Mar. 31, 1928.
668,707	Poetter G.m.b.H. *Process and furnace for the heat treatment of metallic objects.* Jan. 30, 1929.
668,769	E. Friant. *Inalterable alloy and process of making this alloy.* May 15, 1928.
668,820	Société Anonyme pour l'Industrie de l'Aluminium. *Method of, and device for annealing and suddenly cooling metal sheets.* Jan. 31, 1929.
668,825	The Lusifer Products Co. *Process for improving the properties of steel.* Jan. 31, 1929.
668,860	Deutsche Edelstahlwerke Akt.-Ges. *Special steel.* Feb. 1, 1929.
668,719	Wellman Seaver Rolling Mill Co., Ltd. *Improvements to apparatus for making metallic tubing.* Jan. 31, 1929.
668,751	Q. Marino. *Bath for the electrolytic deposition of chromium, cobalt or other metals or alloys.* May 12, 1928.
668,776	Société des Usines du Pied-Selle. *Process and device for making castings of iron and other metals.* May 15, 1928.
668,868	I. G. Farbenindustrie Akt.-Ges. *Process for improving the corrosion resistance of magnesium alloy castings.* Feb. 1, 1929.
666,800	Q. Marino. *Electrolytic bath.* May 18, 1928.
668,865	E. Thibaut and E. D. P. Deburgraeve. *Refractory product for the construction and repair of hearths and furnaces.* Feb. 1, 1929.
669,045	Demag Akt.-Ges. *Rotating cooling bed.* Feb. 4, 1929.
669,109	*Process for refining nickel, copper and copper-nickel alloys.* June 1, 1928.
669,115	Société des Produits Chimiques des Rares Terres (Soc. An.). *Process for treating complex ores of vanadium.* June 11, 1928.
669,145	E. Kamp. *Method of making forged shafts.* Feb. 4, 1929.
669,163	Société Aubert et Duval Frères. *Dies made of nitrided steel.* Feb. 5, 1929.
669,169	F. Kocks. *Method of enlarging hollow bodies.* Feb. 5, 1929.
669,107	A. G. A. Charpy. *Process for regenerating solutions of hydrochloric acid used in pickling iron.* May 31, 1928.
669,231	V. Volpata. *Process for the production of gold and silver.* Feb. 6, 1929.
669,257	National Processes, Ltd. *Improvements to machines for sintering or roasting ores.* Feb. 6, 1929.
669,296	Bohn Aluminum and Brass Corp. *Improvements in the heat treatment of aluminum castings.* Feb. 7, 1929.
669,328	H. A. Waldrich G.m.b.H. *Method of refinishing, by grinding, the inner walls of metallurgical chill molds.* Feb. 8, 1929.
669,475	Mannesmannrohren Werke. *Device for cooling the mandrels of rolling mills.* Feb. 11, 1929.
669,532	C. Brackelsberg. *Process and apparatus for producing gas-free, especially oxygen-free ferrous alloys.* Feb. 12, 1929.
669,551	Siemens & Halske Akt.-Ges., and W. Kroll. *Alloy.* Feb. 13, 1929.
669,564	T. Weymerskirch. *Manufacture of rolls for rolling mills.* Feb. 13, 1929.
669,595	A. Stinville. *Mechanical ore-roasting furnace.* Feb. 13, 1929.
669,307	F. Kylberg. *Process and apparatus for making razor blades and for treating the strip metal used for making them.* Feb. 7, 1929.
669,444	Compagnie Générale des Conduites d'Eau (Société Anonyme). *Centrifugal casting machine and device for pouring the liquid or pulverulent material.* Feb. 9, 1929.
669,446	T. D. Kelly and G. E. Leavey. *Improvements in the refining and mixing of metals and alloys.* Feb. 9, 1929.
669,466	A. Ewen. *Process for making vessels of heat-resistant metal.* Feb. 9, 1929.
669,467	I. G. Farbenindustrie Akt.-Ges. *Process for welding and heating metals and alloys.* Feb. 11, 1929.
669,473	P. Boudier and J. Boudier. *Improvements to electric arc-welding generators.* Feb. 11, 1929.
669,474	Vereinigte Aluminium Werke Akt.-Ges. *Process for obtaining wires of aluminum and aluminum alloys which are of uniform strength throughout their length.* Feb. 11, 1929.
669,578	Les Frères Breguet. *Die holder for wire-drawing machines. Multiple draw bench.* Feb. 13, 1929.
669,585	United States Metals Refining Co. *Process for casting and rolling copper.* Feb. 13, 1929.
669,287	Electric Furnace Co., Ltd. *Improvements to electric induction furnaces.* Feb. 7, 1929.
669,470	Det Norske Aktieselskab for Elektrokemisk Industri. *Method of working electric furnaces.* Feb. 11, 1929.
669,575	J. Stone & Co., Ltd. *Improvements to apparatus used in electroplating metal tubes.* Feb. 13, 1929.
669,347	Compagnie Francaise pour l'Exploitation des Procédés Thomson-Houston. *Process for preparing agglomerated products.* Feb. 8, 1929.
669,380	W. I. Einstein. *Improvements to processes for preparing objects made of organic materials for electroplating with metal.* Feb. 8, 1929.

French Addition Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
35,306	Vereinigte Stahlwerke Akt.-Ges. *Process for producing iron from iron-bearing ores, with the formation of ferric chloride.* (First addition to No. 647,530.) Apr. 6, 1928.
35,304	Sprenger Corporation m.b.H. *Process for producing metallic coatings on objects of aluminum and aluminum alloys.* (First addition to No. 595,422, granted to B. Jirotka and F. Consten.) Mar. 10, 1928.
35,378	Maschinenfabrik Esslingen. *Process for making gray cast iron of any desired structure.* (First addition to No. 623,987.) May 25, 1928.
35,376	Siemens & Halske Akt.-Ges. *High-frequency induction furnace.* (First addition to No. 642,577.) May 25, 1928.

German Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
481,816	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Metal press for making endless lead pipe or for sheathing cables.* Dec. 2, 1924.
482,000	E. Schleicher, Haspe, i.W., Germany. *Method of making cast wood bits.* June 23, 1927.
482,001	Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. *Cooling chamber for bright-annealing furnaces.* Mar. 18, 1927.
482,002	Witkowitzer Bergbau- und Eisenhütten-Gewerkschaft, and C. Salat, Witkowitz, Mähren, Czechoslovakia. *Long-hearth reheating furnace operating without recuperation or regeneration.* Apr. 1, 1926.
481,898	F. M. Köhler, Berlin, Germany. *Process and apparatus for making solutions of metallic salts from ores, alloys, foundry residues and other metallic waste.* June 5, 1926.
481,809	J. Bargou, Stuttgart, Germany. *Cold-rolled light-metal sheet with thin middle section, for welding.* May 21, 1926.
482,202	H. G. E. Cornelius, Stockholm, Sweden. *Process for the direct production of iron or steel or other low-carbon metals and alloys.* (Addition to No. 461,746.) Mar. 30, 1924.
482,203	H. Siewers, Kellinghausen, Holstein. *Process for the direct production of iron by reduction of iron ores and melting of the sponge iron produced.* Oct. 18, 1927.
482,204	B. Young, Frankfurt a.M., Germany. *Process for the direct production of metals, especially iron and steel from ores or residues.* Dec. 10, 1926.
482,276	Berg & Co. Ges. für Industrie-Ofenbau u. Feuerungsbedarf m.b.H., Bergisch Gladbach; and K. Stobrawa, Gleiwitz, Germany. *Furnace for preheating scrap and other solid charge materials for melting furnaces, especially open-hearth furnaces.* Aug. 2, 1927.
482,277	Fried. Krupp Akt.-Ges., Essen a.d. Ruhr, Germany. *Process for hardening the outer layers of cast iron, and cast iron alloy.* Mar. 18, 1927.
482,142	Siemens-Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Pattern for molding complicated castings.* Jan. 23, 1927.
482,218	The H. B. Smith Co., Westfield, Mass. *Method of, and machine for making cored molds for thin-walled hollow castings.* Jan. 24, 1928.
482,041	W. Buess, Hannover, Germany. *Battery of chill molds, especially for casting pigs.* Aug. 8, 1925.
482,042	E. Will, Hamburg, Germany. *Automatic casting machine, especially for making iron castings.* Nov. 11, 1925, in the United States Jan. 26, Jan. 31 and Feb. 16, 1925.
482,313	Hirsch, Kupfer- und Messingwerke Akt.-Ges., and C. Tama, Messingwerk, near Eberswalde, Germany. *Method of, and apparatus for carrying out fusion electrolyses.* Aug. 8, 1928.
482,090	J. Sigmund, Luttein, near Olmütz, Germany. *Method of forming the surfaces of castings which are to be machined.* Dec. 9, 1926.
482,424	J. Hilber, Neu-Ulm, Schwaben, Germany. *Washing drum rotating in an open trough, for washing loamy or clayey material, such as ores or sand.* Feb. 1, 1928.
482,426	Fried. Krupp Grusonwerk Akt.-Ges.; Magdeburg-Buckau, Germany. *Endless classifying grid or the like.* May 13, 1928.
482,427	Guggenheim Brothers, New York, N. Y. *Flotation process for ores and other materials.* May 7, 1927, in the United States Jan. 24, 1927.
482,455	Siemens-Planiawerke A.G. für Kohlefabrikate, Berlin-Lichtenberg, Germany. *Method of making heating elements consisting chiefly of silicon and carbon.* Jan. 28, 1928.
482,373	W. B. Smits, Kassel-Wilhelmshöhe, Germany. *Means for the air-tight and acid-proof sealing of the resistance wires of electric heating elements.* June 8, 1928, in Czechoslovakia Feb. 23, 1928.
482,509	R. C. Krause, Youngstown, Ohio. *Ingot mold in which a temperature gradient is maintained between the side surfaces.* May 31, 1927.
482,537	C. Pardun, Gelsenkirchen, Germany. *Method of obtaining a centrifugally cast pipe which is accurate at the junction between pipe and bell end, using a core for the bell.* Sept. 26, 1926.
482,538	A. Schylla, Düsseldorf, Germany. *Compound metallic core, built up of annular segments, for use in casting hollow ingots, the joints between segments containing a yielding or carbonizable substance.* Aug. 30, 1927.
482,576	C. Ohlrogge, Velbert Rhld., Germany. *Method of making aluminum castings.* Feb. 28, 1927.

Patent No.	Patentee, Subject of Invention, and Filing Date
482,539	E. Bodinet, Dillingen, Saar, Germany. *Method of casting spheres, using a rotary mold.* Nov. 25, 1927.
482,540	E. Brumm, Lyons, France. *Casting machine, in which the molten metal is poured into the mold by hand and is subjected to pneumatic pressure in the mold.* Dec. 15, 1927, in France Dec. 15, 1926.
482,511	Balz-Erzröstrung G.m.b.H., Gleiwitz, Germany. *Mechanical roasting furnace.* Feb. 23, 1927.
482,593	The Dunlop Rubber Co., Ltd., London, England. *Galvanizing annular bodies.* Dec. 1, 1928, in Great Britain Jan. 19, 1928.
482,326	Buderus'che Eisenwerke and M. Zillgen, Wetzlar, Lahn, Germany. *Method of utilizing blast furnace mud.* Nov. 3, 1926.
482,327	O. Keune, Magdeburg, Germany. *Process for making fused Portland cement from blast furnace slag and limestone.* Feb. 27, 1927.
482,357	G. Polysius Akt.-Ges., Dessau, Germany. *Rotary furnace for burning, roasting, sintering all kinds of materials.* Sept. 9, 1926.
481,741	Gewerkschaft Kronprinz, Bonn a.Rh., Germany. *Electric heating device for rod and strip rolling mills.* Feb. 23, 1927.
481,742	J. Doubs, Berlin-Charlottenburg, Germany. *Method of rolling thin sheets, with elevating double-roller tables in front of and behind the rolls.* May 25, 1928.
481,743	Gewerkschaft Wallram, Essen a.d. Ruhr, Germany. *Reversible wire-drawing machine.* Nov. 1, 1927.
481,590	Press- und Walzwerk Akt.-Ges., Reisholz, Germany. *Method of welding seams, especially of tubing, using water gas.* (Addition to No. 462,840.) Dec. 19, 1925.
481,748	A. Goetz, Göttingen, Germany. *High-vacuum, high-temperature electric furnace.* Aug. 12, 1926.
481,735	Siemens-Planiawerke Akt.-Ges. für Kohlefabrikate, Berlin-Lichtenberg, Germany. *Rod-shaped heating element for electric resistance furnaces.* Oct. 1, 1925.
481,597	E. Schröder, Berlin, Germany. *Method for electric resistance welding of aluminum.* Dec. 22, 1927.
481,620	A. Ricard, Paris; P. Devigne, Chatou (Seine-et-Oise); and A. Fouchard, Paris. *Molding process and machine for making molds for hollow castings having projections or cavities on their interior surfaces.* May 20, 1927, in France Mar. 11, 1927.
481,706	Steyr-Werke Akt.-Ges., Steyr, Germany. *Method of making cylinder blocks for internal combustion motors, using a built-up core for the water jacket.* Feb. 3, 1928.
481,621	R. B. Dale, Jamaica, N. Y. *Process for making castings which are free from blow-holes.* Dec. 12, 1926.

Norwegian Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
46,643	Guggenheim Bros., New York, N. Y. *Process for concentrating ores.* May 19, 1927.
46,645	A/S Norsk Staal (Elektrisk-Gas-Reduktion), Trondjhem, Norway. *Construction of high-voltage arc furnace.* Feb. 18, 1925.
46,683	Guggenheim Bros., New York, N. Y. *Process for concentrating ores.* May 20, 1927.
46,684	Guggenheim Bros., New York, N. Y. *Process for concentrating ores.* May 21, 1927.
46,687	Siemens-Elektrowärme G.m.b.H., Sörnewitz, near Meissen, Germany. *Electric salt-bath furnace.* Aug. 30, 1926.
46,708	Metallbank und Metallurgische Gesellschaft Akt.-Ges., Frankfurt a.M., Germany. *Process for purifying aluminum and its alloys.* Jan. 24, 1927, in Germany Feb. 8, 1926.
46,709	P. L. Hulin, Grenoble, Isère, France. *Process for the electrolytic production of light metals.* Feb. 3, 1928, in France Feb. 3, 1927.
46,710	Société Anonyme de Produits Chimiques et Électrométallurgique Alais, Froges et Camargues, Paris, France. *Improvements to electrolytic apparatus for refining aluminum and similar operations.* June 22, 1928, in France July 4, 1927.
46,711	Aluminium-Industrie Akt.-Ges., Neuhausen, Switzerland. *Process for the electrolytic recovery of pure aluminum from crude aluminum, aluminum alloys and the like.* Oct. 15, 1928, in Germany Feb. 4, 1928.
46,737	Allgemeine Elektrizitäts Gesellschaft, Berlin, Germany. *Arc welding apparatus, using a protective gas.* Oct. 20, 1927, in Germany Nov. 9, 1926.
46,742	Société Anonyme Tréfileries et Laminoirs Du Havre, Aciens Établissements Lazare Weiller Société Cooperative de Rugles et la Canalisation Électrique Réunis., Paris, France. *Process for making metallic powder.* Oct. 22, 1928, in France Nov. 16, 1927.
46,743	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Partition for the separation of the products of fusion electrolysis, especially applicable in the electrolysis of magnesium chloride.* Nov. 21, 1928, in Germany Dec. 23, 1927.
46,761	Det Norske Aktieselskab for Elektrokemisk Industrie, Oslo, Norway. *Process for baking electrodes.* June 3, 1927.
46,762	Aktieselskapet Norsk Aluminium Co., Oslo, Norway. *Electrode arrangement.* May 21, 1928.
46,766	A. Jessup, Paris, France. *Process for the electrolytic production of metals, especially magnesium, in two steps.* Sept. 29, 1926.
46,797	N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands. *Process for soldering tungsten and molybdenum.* Nov. 9, 1927.

Swedish Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
67,595	G. T. Southgate, Calhoun, Ga., U. S. *Method of, and apparatus for heating furnaces, using a combination of a flame and an arc.* Apr. 18, 1925, in the United States May 7, 1924.
67,625	Aktiebolaget Ferrolegeringar, Trolhättan, Sweden. *Process for producing low-carbon ferrochromium alloys.* (Addition to No. 66,850.) July 26, 1923.
67,626	H. Grünewald, Hilchenbach, Germany. *Annealing furnace construction.* May 5, 1925.
67,334	Akt.-Ges. Brown, Boveri & Cie., Baden, Switzerland. *Hydraulic drive for vertical electrodes of electric melting furnaces.* May 7, 1926, abroad Oct. 16, 1926.
67,641	H. G. Torulf, Stockholm, Sweden. *Igniting device for sintering pots.* Dec. 6, 1926.
67,648	G. Michell, Bagneux, France. *Process for protecting easily-oxidizable alloys.* Mar. 9, 1928, abroad Mar. 12, 1927.
67,666	B. Quast and F. Lomberg, Bodenkirchen, near Köln, Germany. *Conveyor for rolling mills.* Nov. 20, 1928, abroad Jan. 25, 1928.
67,673	Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. *Process for the direct utilization of finely divided substances, which are to be melted in shaft furnaces.* Oct. 5, 1926, abroad Apr. 6, and Sept. 8, 1926.
67,687	H. Eriksson, Sköldinge, Sweden. *Apparatus for mixing ore slime or the like with fuel or other similar materials.* June 16, 1926.
67,706	H. S. Potter, Johannesburg, South Africa. *Process for making hollow drill rods.* May 3, 1927, abroad May 4, 1926.
67,735	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Process for obtaining potassium from potassium fluoride.* July 18, 1928, abroad Aug. 5, 1927.
67,736	Aluminum Company of America, Pittsburgh, Pa. *Electrolytic process for refining aluminum.* Dec. 20, 1923, abroad Dec. 21, 1922.
67,761	H. G. E. Cornelius, Stockholm, Sweden. *Process for producing low-carbon metals and alloys.* (Addition to No. 64,288.) Jan. 12, 1924.
67,775	Aluminum Company of America, Pittsburgh, Pa. *Process for producing corrosion-resistant aluminum alloy objects.* Apr. 8, 1927, abroad Jan. 22, 1927.
67,777	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Process for purifying magnesium and high-percentage magnesium alloys.* (Addition to No. 59,257.) Oct. 27, 1927, abroad Nov. 13, 1926.
67,778	M. G. Corson, Jackson Heights, N. Y. *Method of heat treating a copper-nickel-beryllium alloy, and alloy thus treated.* Nov. 14, 1927.
67,799	W. Schäfer, and Erz und Kohle Flotation m.b.H., Bochum, Germany. *Process for the concentration of floatable material.* Feb. 24, 1928, abroad May 4, 1927.
67,800	K. G. Hallin, Bofors, Sweden. *Method of making rolls.* Oct. 12, 1927.
67,813	Akt.-Ges. Brown, Boverie & Cie., Baden, Switzerland. *Device for sealing the cylindrical electrodes of electric melting furnaces.* Dec. 18, 1926, abroad Jan. 2, 1926.
67,814	Almänna Svenska Elektriske, Västeras, Sweden. *High-frequency electric furnaces.* Mar. 5, 1928.
67,817	Aktiebolaget Axel Christiensson, Stockholm, Sweden, and Aktiebolaget Eksjö Mekanisk Verkstad, Eksjö, Sweden. *Sand-slinging machine.* May 12, 1927.
67,843	Aktiebolaget Platföradling, Hälsingborg, Sweden. *Method of joining together radiator sections.* Oct. 6, 1925.
67,898	F. Krupp Akt.-Ges., Essen, Germany. *Non-magnetic or weakly magnetic cast iron.* June 14, 1927, abroad July 9, 1926.
67,916	F. Krupp Grusonwerke, Magdeburg-Buckau, Germany. *Process for working up complex ores and smelter products.* Dec. 29, 1926, abroad Jan. 26, 1926.
67,917	Norddeutsche Affinerei, Hamburg, Germany. *Process for eliminating arsenic from smelter products.* Oct. 7, 1927, abroad Mar. 3, 1927.
67,918	T. D. Kelley, London, England. *Alloy.* Aug. 31, 1927, abroad Sept. 10, 1927.
67,919	Finspongs Metallverk AB, Finspong, Sweden. *Method of charging induction melting furnaces having an ironless transformer core.* Oct. 12, 1927, abroad Dec. 23, 1926.
67,925	American Machine and Foundry Co., New York, N. Y. *Lead alloy for soldering.* Nov. 1, 1927.
67,937	Fagersta Bruks AB, Fagersta, Sweden. *Hollow drill rod and process for making same.* Dec. 1, 1927.
67,938	Aktiebolaget Svenska Kullagerfabriken, Göteborg, Sweden. *Rolling mill.* Sept. 1, 1928.
67,995	I. Rennerfelt, Djursholm, Sweden. *Apparatus for the electrical generation of heat.* July 3, 1926.
67,999	N. O. Hedman, Älvsbyn, Sweden. *Process for hardening copper.* June 15, 1927.
68,017	W. Kunst, Barmen, Sweden. *Process for making seamless tubing.* Jan. 31, 1927.
68,056	Aktiebolaget Ferriconcentrat, Stockholm, Sweden. *Process for concentrating oxidic* (Fe_2O_3) *iron ores.* Oct. 28, 1926.
68,057	Mannesmann-röhren Werke, Düsseldorf, Germany. *Process for rolling tubing.* (Addition to No. 65,368.) Dec. 30, 1927, abroad Aug. 20, 1927.
68,072	H. Skappel, Oslo, Norway. *Process for breaking up complex ores, concentrates, etc.* Feb. 25, 1924, abroad Feb. 26, 1923.
68,073	Metallgesellschaft Akt.-Ges., Frankfurt a.M., Germany. *Process for extracting zinc from oxidic zinc compounds.* Sept. 28, 1928, abroad Oct. 13, 1927.
68,144	Aktiebolaget Birka Regulator, Stockholm, Sweden. *Thermostatic device for regulating the input to electric heating apparatus.* Sept. 30, 1920.
68,149	H. S. Mackay, London, England. *Process for the electro-chemical treatment of copper ores.* May 22, 1925, abroad May 29, 1924.
68,180	H. G. A. von Kantzow, Hallstahammar, Sweden. *Iron alloy.* Dec. 15, 1926.
68,191	Siemens & Halske Akt.-Ges., Berlin-Siemensstadt, Germany. *High-frequency induction furnace.* July 20, 1927, abroad July 24, and 29, and Sept. 11, 1926.
68,228	G. Martin, Wembley, England. *Process for roasting, calcining, or sintering ores, or calcareous or other raw materials in the form of powder.* May 4, 1927, abroad May 17, 1926.
68,240	Allegemeine Elektrizitäts Gesellschaft, Berlin, Germany. *Electric annealing furnace.* Oct. 15, 1926.

Swiss Patents

Patent No.	Patentee, Subject of Invention, and Filing Date
131,920	Siemens & Halske, Berlin-Siemensstadt, Germany. *High-frequency induction furnace.* Sept. 26, 1927, in Germany June 10, 1927.

Patent No.	Patentee, Subject of Invention, and Filing Date
131,963	G. Michel, Bagneux, Seine, France. *Process for protecting easily oxidizable metals.* (Addition to No. 118,978.) Mar. 10, 1928, in France Mar. 12, 1927.
132,040	R. Appel, Berlin, Germany. *Process for the electrolytic deposition of metallic chromium for the production of chromium platings on other metals.* July 20, 1927, in Germany July 21, 1926.
132,041	Leipziger Schnellpressfabrik Akt.-Ges., vormals Schmiers, Werner & Stern, Leipzig, Germany. *Method of making places for adherence of electrolytic deposits on light metal bodies.* May 25, 1928, in Germany Feb. 4, 1928.
132,073	Vulcan-Feuerung Akt.-Ges., Köln, Germany. *Method of, and device for injecting water into the melting zone of shaft melting-furnaces or blast furnaces.* Feb. 3, 1928.
132,074	Gräflich Schaffgotts'che Werke G.m.b.H., Gleiwitz, Germany. *Method of working electrothermic processes.* Mar. 26, 1928.
132,083	C. Archer, Meximieux, Ain, France. *Method of mounting diamonds used as dies in drawing metallic wire.* Mar. 19, 1928, in France May 9, 1927.
132,143	Société Électrométallurgique de Montricher, Paris, France. *Electric furnace electrode.* Dec. 13, 1927, in France Dec. 21, 1926 and Oct. 13, 1927.
132,144	W. Hammer, Freiburg i.B., Germany. *Method of electrically heating furnaces, such as melting, annealing, and hardening furnaces, by means of heating resistances through which flow induced currents.* Apr. 30, 1928, in Germany June 2, 1927.
132,369	E. Manos, Geneva, Switzerland. *White, inoxidizable alloy.* Oct. 15, 1928.
132,370	Societá Alti Forni, Fonderi, Acciaierie e Ferriere Franchi Gregorini Brescia, Italy. *Tubular mold for making pipes by centrifugal casting.* June 12, 1928.
132,371	C. Rötzel, Köln, Germany. *Process for rolling thin strip iron.* Apr. 21, 1928, in Germany May 5, 1927 and Apr. 7, 1928.
132,372	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Process for extruding shapes.* Jan. 12, 1928, in Germany Feb. 9, 1927.
132,438	Société Électrométallurgique de Montricher, Paris, France. *Suspension device for the holding ring of an electric furnace electrode.* Dec. 13, 1927, in France Dec. 28, 1926 and Oct. 26, 1927.
132,655	A. Geyer, Paris, France. *Process for making aluminum alloys.* Jan. 26, 1928, in France Feb. 4, 1927.
132,656	Société d'Expansion Technique. *Machine for making pipes of all kinds by centrifugal casting, especially metal pipes.* May 9, 1928, in France May 19, 1927.
132,657	International De Lavaud Manufacturing Corp., Ltd., Toronto, Ont. *Centrifugal mold for pipes and process for making it.* May 19, 1928, in the United States June 8, 1927.
132,659	A. Sund, Luxemburg-Eich, Luxemburg. *Electric welding burner.* May 25, 1928, in Luxemburg May 27, 1927.
132,727	P. E. Bunet, Versailles; and Société Anonyme de Gennevilliers, Gennevilliers, Seine, France. *Magnetic-core induction furnace.* May 29, 1928, in France June 2, 1927.
132,728	P. E. Bunet, Versailles; and Société Anonyme de Gennevilliers, Gennevilliers, Seine, France. *Induction furnace.* May 29, 1928, in France June 2, 1927.
132,817	Maschinenfabrik Esslingen, Esslingen a.N., Germany. *Process for making cast iron of any desired structure.* (Addition to No. 122,395.) May 21, 1928, in Germany May 27, 1927.
132,965	K. Emmel, Mülheim a. Ruhr; and Vereinigte Stahlwerke Akt.-Ges., Düsseldorf, Germany. *Method of making superheated cast iron melts in the cupola.* Feb. 27, 1928, in Germany Mar. 15, 1927.
132,966	Electro Metallurgical Co., New York, N. Y. *Process for decarburizing ferrous alloys.* Apr. 7, 1928.
132,967	Vereinigte Aluminium Werke Akt.-Ges., Lautawerk-Lausitz, Germany. *Process for making aluminum-silicon alloys.* Jan. 5, 1928.
133,210	Udylite Process Co., Kokomo, Ind. *Process for electroplating cadmium from cadmium baths containing potassium cyanide.* Mar. 24, 1927, in the United States Mar. 31, 1926.
133,249	J. Lavanchy, Lutry, Waadt, Switzerland. *Alloy.* July 16, 1928.
133,250	Elektrizitätswerke Lonza (Gampel und Basel), Basel, Switzerland. *Process for producing aluminum and aluminum alloys from alumina.* Aug. 4, 1927, in Germany Sept. 18, 1926.
133,251	Aluminium Industrie Gesellschaft, Neuhausen, Switzerland. *Process for the electrolytic production of magnesium from metallic material containing magnesium.* Nov. 23, 1927.
133,252	Société Anonyme de Produits Chimiques et Electrometallurgique Alais, Froges et Camargues, Paris, France. *Apparatus for the electrolytic production of light metals.* June 8, 1928, in France July 4, 1927.
133,252	W. Koehler, Cleveland, Ohio. *Process for the simultaneous production of metallic magnesium and calcium carbide.* Aug. 8, 1927.
133,254	Bohn Aluminum and Brass Corp., Detroit, Mich. *Casting mold.* Mar. 30, 1928.
133,255	P. Haessler, Nüremburg, Germany. *Die-casting machine for metals having a high melting point.* July 9, 1928, in Germany Oct. 21, 1927.
133,261	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Process for making heat- and corrosion-resistant surfaces on iron.* Apr. 23, 1928, in Germany Apr. 29, 1927.
133,484	The Firm: Albert Butziger, Leipzig, Germany. *Process for chromium plating cast iron.* June 18, 1928, in Germany June 20, 1927.
133,519	Aluminium Industrie Akt.-Ges., Neuhausen, Switzerland. *Process for the electrolytic production of magnesium.* Dec. 4, 1927.
133,520	Societá Alti Forni, Fonderi, Acciaierie e Ferriere Franchi Gregorini, Brescia, Italy. *Centrifugal pipe-casting machine.* June 12, 1928.
133,526	S. Junghans, Villingen, Baden, Germany. *Process for treating raw, half-finished, and finished materials, especially metals for the purpose of influencing their crystal structure and properties.* Feb. 10, 1928.
133,527	F. Krupp Akt.-Ges., Essen, Germany. *Method of increasing the yield point of alloy steels whose yield point cannot be raised by heat treatment, especially applicable to hollow bodies having an austentic structure.* June 4, 1928, in Germany June 23, 1927.
133,528	G. Hammesfahr, Solingen-Foche, Germany. *Method of obtaining edge-holding hardness in rustless knives and shears of all kinds.* July 14, 1928, in Germany July 26, 1927.
133,610	I. G. Farbenindustrie Akt.-Ges., Frankfurt a.M., Germany. *Method of charging electric furnaces.* May 8, 1928.
133,611	Siemens Schuckertwerke Akt.-Ges., Berlin-Siemensstadt, Germany. *Block for holding heating resistances.* July 18, 1928.
133,612	E. Bornand, and H. Arnold, Geneva, Switzerland. *High-frequency induction furnace.* Nov. 3, 1928.

Announcement

Development of a new metal known as "Konel," which is credited with being much stronger than other metals at high temperatures and which can be used extensively in the moving parts of internal combustion engines and other extremely hot places, has been announced by the Westinghouse Electric and Manufacturing Company. The announcement followed the granting of foreign patent rights.

Originally developed by the Westinghouse Research Laboratories as a substitute for platinum in the manufacture of filaments for radio tubes, the new metal was discovered to be harder to forge than steel, and to be very tough at high temperatures, when most metals lose their strength.

The new metal was created by Dr. E. F. Lowry, a graduate of Ohio State University. Platinum costs approximately $180 per ounce, while the new substance costs only a few dollars a pound. Life of Konel filaments is approximately ten times longer than other filaments. Tubes with filaments made of the new metal are operated 175 degrees colder than tubes with platinum filaments but with the same emission, thereby giving better reception results.

A Correction

In Dr. H. F. Moore's Note in the August issue of METALS & ALLOYS, on the Ikeda Test on page 70.

The endurance for "Annealed Copper" by the Ikeda Test is erroneously stated as being 29,800 lb. per sq. in., whereas it should read 9,800 lb. per sq. in.

Arc Welding. Lincoln Prize Papers submitted to The American Society of Mechanical Engineers. Edited by Edward P. Hulse. McGraw-Hill Book Company, New York, 1929. Cloth, 6 × 9 inches, 421 pages. Price, $5.00.

The seven papers published in this book include the papers of the three prize winners, the two that received honorable mention, and two other papers of unusual merit submitted for the three Lincoln Arc Welding prizes given by the Lincoln Electric Company and awarded by the American Society of Mechanical Engineers. The papers are "Arc-Welding, Its Fundamentals and Economics," James W. Owens, "Fundamental Principles of Arc-Welding," H. Dustin; "Electric Welding of Ship's Bulkheads and Similar Plated Structures," H. E. Rossell; "Theory and Application of the Base Plate Arc-Welded Rail Joint," F. B. Walker; "Stable Arc Welding on Long-Distance Pipe Lines," B. K. Smith; "Arc Welding as Applied to Construction Work at the Philadelphia Navy Yard," M. W. Kennedy and F. H. Wieland; "Arc Welding of Duplicate Steel Structure," W. H. Himes.—D. L. MATHIES.

Patents and Trade Marks!
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Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment, should be of interest to the readers of METALS & ALLOYS. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* METALS & ALLOYS *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department.*—EDITOR.

Bethlehem Mayari Pig Iron.—Booklet No. 26-A gives applications and analysis specifications for the use of Mayari iron for special purposes. This booklet also includes a discussion of cupola practice and metallurgy of iron with nickel-chromium. Bethlehem Steel Company, Bethlehem, Pa.

Published by the same firm, "Silvery Mayari Pig Iron." Booklet describes a product said to be a new general-purpose pig iron for making super-strength castings.

Blowpipes, Tips and Burners.—Bulletin No. 6 describes a variety of blowpipes, tips and burners. American Gas Furnace Company, Elizabeth, N. J.

Furnaces.—Bulletin 295 describes heat-treating and carburizing furnaces of the enclosed front type. W. S. Rockwell Co., 50 Church Street, New York, N. Y.

Electrically Heated Laboratory Apparatus.—This literature illustrates hot plates, thermometer calibration tanks, heating furnaces, melting furnaces, etc. Leaflet TA-23. Harold E. Trent Co., 439 North 12th St., Philadelphia, Pa.

Industry's Most Reliable Pyrometer.—Bulletin B-6-P 400-529 covers the potentiometer pyrometer for industrial temperature control. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

Instrument Investment News.—The July issue of this publication contains the following articles: Kraut Flavor Depends on Proper Cooking; High Pressures and Temperatures Require Finest Accessories; Temperature Control the Basis of Successful Chromium Plating; Railroad Air Brakes Tested for Safety; Bleaching Textiles a Thermal Operation. Consolidated Ashcroft Hancock Co., Inc. 11 Elias St., Bridgeport, Conn.

Metal Cleaning.—"Scale," an illustrated folder illustrating a metal scale removing process and offering fuller particulars of specific applications for metal cleaning, tumbling, polishing, dipping, drying and pickling. N. Ransohoff, Inc., 5000 Spring Grove Ave., Cincinnati, Ohio.

Drawing Dies.—Bulletins 101 and 102 describe equipment required and method employed for repolishing and resizing Un-Widia Alloy Dies. Union Wire Die Corporation, 333 West 52nd St., New York, N. Y.

Scovill Cap and Machine Screws.—Catalog S-6. Very attractive and useful booklet, thumb indexed. Illustrated. Tables of prices. Reference tables, etc. Scovill Manufacturing Co., Waterbury, Conn.

Published by the same firm, "Scovill Condenser Tubes," "Specifications for Seamless Muntz Metal Condenser Tubes," "Specifications for Seamless Admiralty Condenser Tubes for Condensers, Distillers and Feed-Water Heaters and Ferrules for Same."

Catalog of TAG Oil Testing Instruments.—Catalog No. 699C covers the standard instruments for making tests of petroleum products. Fully illustrated and described. C. J. Tagliabue Mfg. Co., 18—33rd St., Brooklyn, N. Y.

Published by the same firm, "Better Chromium Plating," leaflet on the subject. Contains typical layout for Chromium Plating Room and other illustrations.

The Practical Use of X-Ray in Industry.—Interesting pamphlet prepared to acquaint manufacturers with some of the profitable uses of X-rays in industrial work. The Kelley-Koett Mfg. Co., Covington, Ky.

Norton Heavy Duty Refractories.—Booklet on this subject. Illustrated. Full information, tables, etc. Norton Co., Worcester, Mass.

Published by the same firm, "Grinding Wheel Information," "Artificial Abrasives, Their History and Development."

SCH Industrial Furnaces.—Interesting booklet illustrating and describing these furnaces for gas, electric and oil. Also furnace room accessories. Typical layouts. The Strong, Carlisle & Hammond Co., Cleveland, Ohio.

Alpha Condenser Tubes.—Specifications, analyses and explanation of Alpha brass condenser tubes. Chase Brass & Copper Co., Inc., Waterbury, Conn.

Nichrome B.—Booklet illustrating and describing this product for fine close-grained iron. Driver-Harris Co., Harrison, N. J.

Vitreosil for the Laboratory.—Leaflet containing full information on this heat-proof, acid-proof product. The Thermal Syndicate, Ltd., 58 Schenectady Ave., Brooklyn, N. Y.

Published by the same firm, "Vitreosil Laboratory Utensils," "Where Conditions Are Corrosive and Temperatures Are High," "Vitreosil Serrated Crucible, Ltd.," "Vitreosil for the Coal Chemist," "Revised Price List of Vitreosil Apparatus for the Chemical Industries," "About Vitreosil."

"How Hot?"—Leaflet illustrating and describing Foxboro instruments for indicating, controlling and recording. The Foxboro Co., Foxboro, Mass.

Improvement Always Comes.—Leaflet illustrating and describing Stow Paint Shop and Metal Finishing Units. Stow Mfg. Co., Inc., Binghamton, N. Y.

Hardening Better Tools with Less Effort.—Bulletin No. 19. Describes the Hump Method of hardening tools. Leeds & Northrup, 4901 Stenton Avenue, Philadelphia, Pa.

Houghton's Black and White.—Very interesting series of booklets prepared by the Houghton Research Staff to circulate more and better technical information pertaining to industries upon those topics with which the Houghton staff in particular are much more familiar than anyone else. In simple and concise language. E. F. Houghton Co., Philadelphia, Pa.

Centrifuges.—Leaflet illustrating and describing electric hand power and water power centrifuges. Prices. Williams, Brown & Earle, Inc., 918 Chestnut Street, Philadelphia, Pa.

Byers Genuine Wrought Iron Pipe.—Folder containing Bulletin No. 26-A, "What Is Wrought Iron," No. 32, "Corrosion of Wrought Iron, Cast Iron and Steel Pipe," No. 38, "The Installation Cost of Pipe," No. 41, "Some Facts about Galvanized and Other Coated Pipe." Also extracts from a Committee Report submitted to the Convention of the Air Brake Association, "Pipe Failures in Railway Service." A. M. Byers Co., Pittsburgh, Pa.

The Story of Udylite.—Interesting book containing information on this rust-proofing agent. Many illustrations. Test tables. The Udylite Process Company, 3220 Bellevue Avenue, Detroit, Michigan.

Amsco.—Attractive loose-leaf folder containing information on Fahralloy castings for high temperature and corrosive processes. Many illustrations. Southern Manganese Steel Co., St. Louis, Mo.

Published by the same firm, "Heat-Resisting Alloys," booklet containing notes on the selection, design and use of castings for high temperature service. Also "Fahralloy for Every Heat and Corrosion Resistant Purpose."

Parker Rust-Proofing Process.—Attractive booklet on the subject of rust-proofing. Profusely illustrated. Processing layouts. Full line of "Parkerized" products. Parker Rust-Proof Co., Detroit, Michigan.

Chapman-Stein Recuperative Furnaces.—Bulletin No. 1 illustrates and describes this type of furnace and soaking pit. The Chapman-Stein Co., Mt. Vernon, Ohio.

Published by the same firm, "The Chapman Continuous Producer."

The End of Rust Troubles.—Attractive booklet on the subject. Contains cutaway elevation of house showing complete installation of brass pipe plumbing. Copper & Brass Research Association, 25 Broadway, New York, N. Y.

Published by the same firm, "Physical Properties of Copper," "Some Approved Methods of Testing Plumbing Installations," "The Story of Yesterday and Today," "Copper Shielding for Radio" (practical suggestions for the use of sheet copper in shielding radio receiving sets), "Coloring Copper and Brass."

M-S-A First Aid Materials.—Catalog No. FA-1 contains full line of first aid material and equipment. Price list. Mine Safety Appliances Co., Braddock Ave. & Thomas Blvd., Pittsburgh, Pa.

Published by the same firm, "Practical Aspects of Resuscitation." Interesting booklet containing much useful information on this subject.

Barnstead Automatic Water Stills.—Catalog A. A complete handbook of Barnstead Water Distilling Apparatus for all purposes, scientific, industrial, commercial, professional and domestic. Fully illustrated and contains much useful and helpful matter. Barnstead Still and Sterilizer Co., Inc., Boston, Mass.

Grefco—A Distinctively Different High Temperature Cement.—Booklet illustrating and describing this product. General Refractories Co., 117 South 16th Street, Philadelphia, Pa.

Published by the same firm, "Methods of Research Newly Applied to Refractories."

First Aid for Furnace.—Leaflet illustrating and describing fire brick. Standard shapes, sizes, etc. Evens & Howard Fire Brick Co., St. Louis, Mo.

Published by the same firm, "The Two from Texas," "Saves You Freight—Made in Texas," "Endurance," all companion leaflets to the above.

Standardalloy.—Leaflet illustrating and describing heat and acid resisting castings. Information on design and fabrication, nickel-chromium, chrome-iron and engineering service. The Standard Alloy Co., Inc., 1679 Collaner Road, Cleveland, Ohio.

Published by the same firm, "Carburizing Boxes and Containers."

U. S. Galvanizing & Plating Equipment Leaflet.—Illustrates and describes equipment for plating, electro-plating, cleaning, pickling, acid-dipping, neutralizing, rinsing, drying and allied operations. U. S. Galvanizing & Plating Equipment Corp., 32 Stockton St., Brooklyn, N. Y.

Oxy-Acetylene Tips.—Interesting monthly publication, the purpose of which is to present to Linde users ideas which they may use to make Linde products of greater help and profit. Much useful and valuable information. The Linde Air Products Co., 30 East 42nd St., New York, N. Y.